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THE SPREAD OF THE SPOTTED ALFALFA APHID, THERIOAPHIS MACULATA (BUCKTON), IN CALIFORNIA[1]

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THE MOST destructive and spectacular pest of alfalfa ever to enter California has spread rapidly throughout the length of the state within the span of four years and has caused over 35 million dollars in direct damage to alfalfa and in costs of control. This pest, the spotted alfalfa aphid, *Therioaphis maculata* (Buckton) (figs. 1, 2, and 3), is an Old World adventive. It apparently first became established in the desert regions of the southwestern United States and then spread so rapidly in California that at times it was difficult to follow its movements. In the spring of 1954, it undoubtedly occurred from southern California to western Texas (Dickson, Laird, and Pesho, 1955; Tuttle and Butler, 1954). It now occurs in most of the alfalfa-producing regions of the United States (see fig. 20) except the Pacific Northwest[3] and the New England states. Many economically important insects have been introduced into North America (Popham and Hall, 1958), but none has spread so rapidly or has caused such destruction in so short a space of time. For this and other obvious reasons, it seems worthwhile to record in some detail the spread of this pest throughout California.

The term *spread* is used here as a movement by some portion of a species which results in a major modification of its geographical range. Spread may start from the periphery of a species distribution when the barrier which prevented the spread is temporarily or permanently removed (for example, *Diabrotica balteata* LeConte across the deserts from Yuma into southern California), or when through evolution a peripheral population is modified so that it can cross the barrier [for example, *Hypera postica* (Gyllenhal) northward into Canada]. The barrier to spread may be a physical barrier such as a desert or mountain range, or it may be a biological barrier such as the absence of suitable host plants. Spread may also occur when some portion of the species is transported to and becomes established in a disjunct, but suitable ecological area (for example, *Therioaphis maculata* into southwestern United

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[3] In the 1958 growing season, the spotted alfalfa aphid was discovered in the Columbia River drainage system in Washington, Oregon, and Idaho.

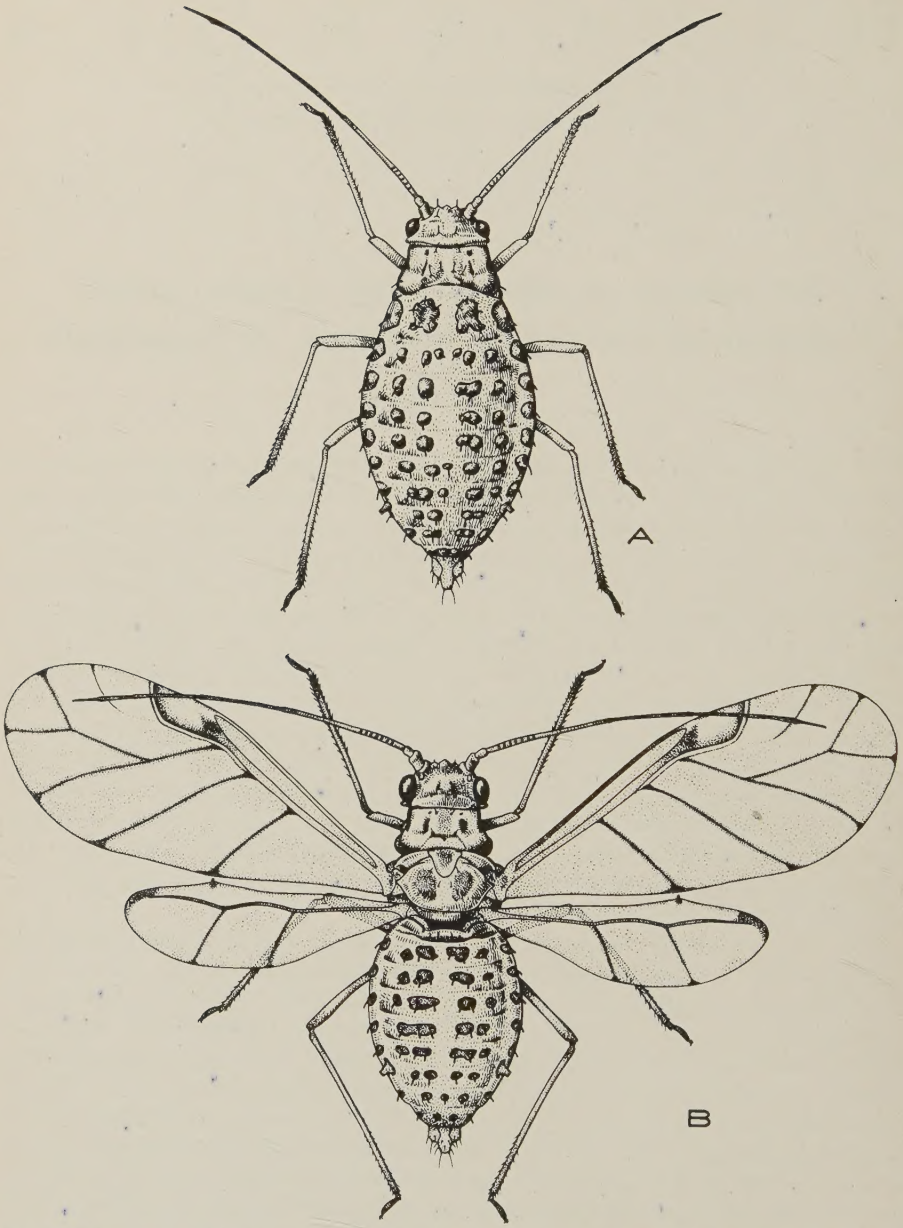

Fig. 1. Parthenogenetic forms of *Therioaphis maculata* (Buckton): *A*, apterous female; *B*, alate female. (Enlarged 25 times.) (Drawing by Celeste Green.)

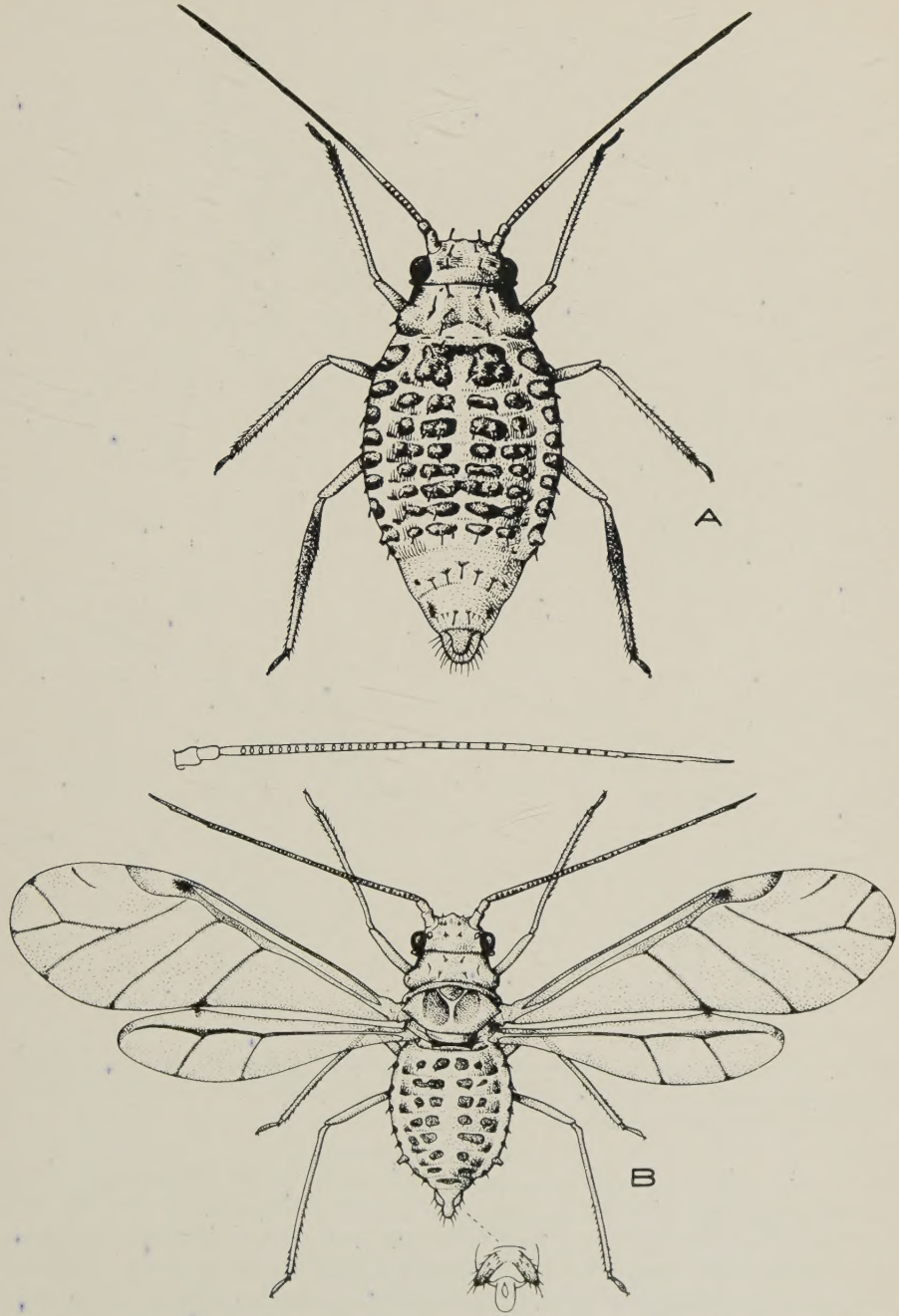

Fig. 2. Sexual forms of *Therioaphis maculata* (Buckton): *A*, female; *B*, male. (Enlarged 25 times.) (Drawing by Celeste Green.)

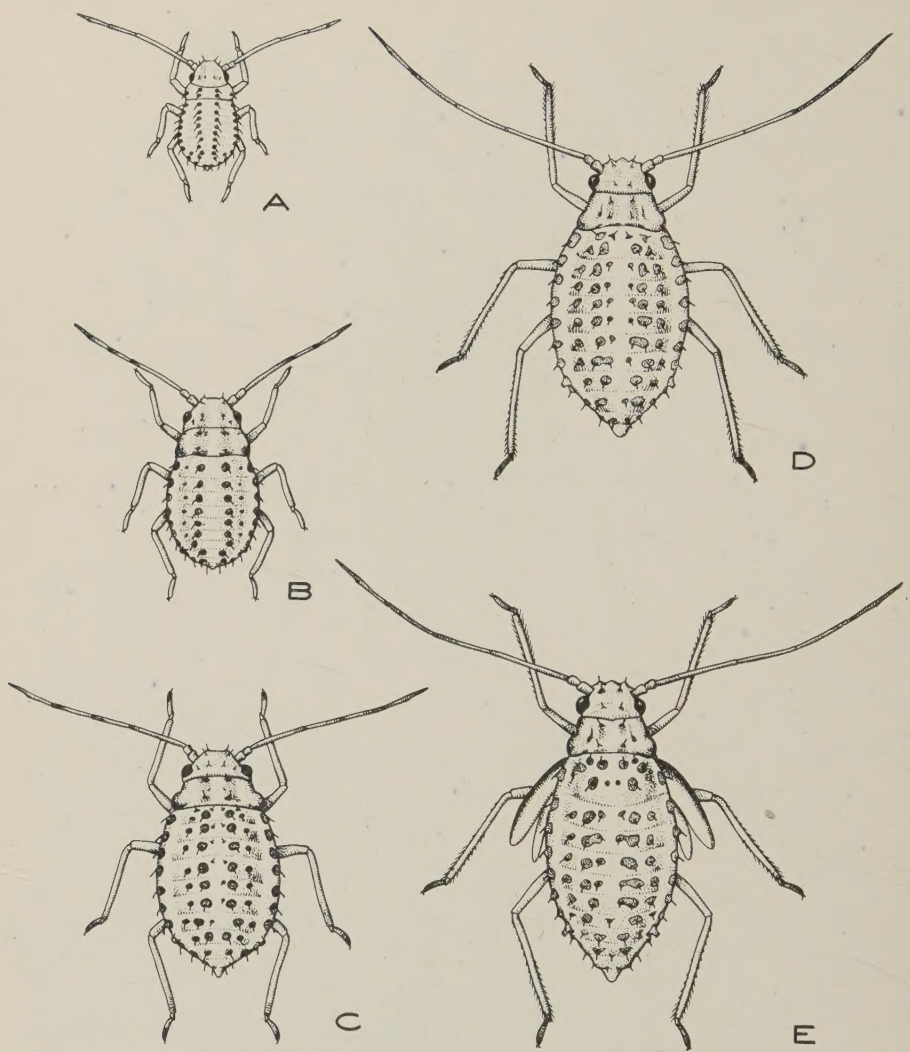

Fig. 3. Developmental stages of *Therioaphis maculata* (Buckton): *A*, first instar; *B*, second instar; *C*, third instar; *D*, apterous fourth instar; *E*, alate fourth instar. (Enlarged 25 times.) (Drawing by Celeste Green.)

States from the Mediterranean region). It is conceivable that some eradicating force may temporarily reduce the extent of a species' geographical range and thus permit it to spread more than once into the same geographical area, but usually spread is a nonrecurrent movement. In contrast, *dispersals* are recurrent local movements within the geographic range of the species. Dispersals cause a redistribution of the individuals of the population, that is, a new *dispersion*. This permits the recolonization of areas within the geographical range as they become suitable after changes in population density,

weather, and other environmental influences affecting the species. *Dispersal* movements are usually indeterminate and at random; consequently, the species will occasionally be taken outside of its geographic range. In most such movements, successful colonization of new areas does not occur and spread does not result. In the history of a species, spread occurs very rarely; dispersals are common occurrences.

It is obvious today that the spotted alfalfa aphid found conditions in California very favorable for its spread. It is apparently a native of the Mediterranean region, an area that has a climate with environmentl influences very similar to that of California. However, other pests of alfalfa have entered California from that general part of the world, and from elsewhere, without making such a rapid and spectacular spread. The alfalfa weevil, *Hypera postica* (Gyllenhal), was first found in Utah in 1904. By 1923, it reached the eastern portion of California; and in 1932, it was discovered in the commercial alfalfa-growing districts of central California. Even as late as 1957, small additions to its distribution were made. Thus, in over fifty years the alfalfa weevil could not accomplish what the spotted alfalfa aphid has in less than five. More recently, in the spring of 1939, the Egyptian alfalfa weevil, *Hypera brunneipennis* (Boheman), was found in the Yuma Valley of Arizona and in the adjacent part of California. Ten years later it had spread to other desert regions of southern California and it now occurs over most of southern California (Reynolds, Anderson, and Deal, 1955).

The ability of this aphid to produce large numbers of alate forms when conditions become unfavorable (Paschke, 1958), and its parthenogenetic reproduction undoubtedly contribute greatly to its ability to spread, in contrast to such slow-moving forms as *Hypera postica* and *H. brunneipennis,* which rarely fly. On the other hand, it appears to be able to achieve higher population levels than two other widespread, economically important aphids that occur on alfalfa in California. The pea aphid, *Macrosiphum pisi* (Harris), and the cowpea aphid, *Aphis medicaginis* Koch, are found together on alfalfa in many areas of the state. In comparison to the spotted alfalfa aphid, the pea aphid occasionally, and the cowpea aphid rarely, become serious pests. The principal reason for their low numbers is the numerous native enemies, including hymenopterous parasites, fungus diseases, and several predators which keep these aphids in check. The spotted alfalfa aphid was introduced into the United States without its parasites and predators, and probably without fungus diseases. The hymenopterous parasites of the pea aphid and cowpea aphid do not effectively attack the spotted alfalfa aphid. Although some of the native predators and apparently the fungus diseases did transfer their attacks to the spotted alfalfa aphid, they did not seem to be effective in many fields in the summer months.

In addition to this lack of natural enemies, *Therioaphis maculata* encountered an almost unlimited food supply. Over one million acres of irrigated alfalfa are grown in California and most of the insect-pest problems are of a minor or local nature as compared to the spotted alfalfa aphid. This is especially true during the hot weather.

Thus, it would appear that when the spotted alfalfa aphid entered the southwestern United States, it found an almost unlimited food supply, few

natural enemies, and physical conditions, at least during a major portion of the year, well suited for rapid reproduction. These three factors coupled with its great ability to spread and disperse, phenomenal rates of increase, and the lack of major physical barriers are the explanation of its rapid spread throughout California.

GENERAL HISTORY OF SPREAD

For detailed records of the spread of *Therioaphis maculata* (Buckton) in California consult the Appendix.

As has been reported earlier (Dickson, Laird, and Pesho, 1955; Armitage, 1954, 1955; Reynolds and Anderson, 1955), the spotted alfalfa aphid was first

TABLE 1

ESTIMATED INFESTATIONS AND LOSSES FROM THE SPOTTED ALFALFA APHID IN CALIFORNIA

Year	Area infested		Treatment costs,* dollars	Estimated damage,* dollars	Total loss,* dollars
	Acres infested	Per cent of state total			
1953	0	0	....	....	....
1954	182,300	18.7	....	....	337,900
1955	827,200	84.9	3,525,000	9,330,000	12,855,000
1956	934,500	95.9	5,325,000	5,275,000	10,600,000
1957	950,400	97.5	4,485,100	5,219,700	9,704,800

* Based on estimates made by County Agricultural Commissioners and compiled by the State Department of Agriculture. (Lockwood, 1954, 1955, 1956, 1957)

noticed to be damaging alfalfa in California in mid-June, 1954 (fig. 5).[4] During the previous month damaging infestations had been encountered at various points in southern Arizona (Tuttle and Butler, 1954). The fact that this aphid did not appear in any of the extensive aphid trapping conducted by R. C. Dickson in 1953 and in early 1954 is strong evidence that this pest was a recent arrival in 1954 or perhaps late 1953. Its pattern of activity since then also indicates that it could not remain long undetected in any warm region.

Almost simultaneously with its discovery in the Imperial Valley it was observed in the Palo Verde Valley. By the end of that year, Riverside and Imperial counties were judged to be completely infested and scattered infestations had been found in San Diego, Los Angeles, and San Bernardino counties. At that time 72 per cent of the alfalfa acreage in southern California and 19 per cent of the state's acreage was reported to be infested (fig. 4). It had also been found in Nevada, Colorado, and Oklahoma, and it probably occurred in other states (figs. 6 and 7).

By the end of June in the year of its discovery, the spotted alfalfa aphid had already seriously damaged about a thousand acres of alfalfa in the Im-

[4] Specimens of *Therioaphis* collected by R. F. Wilkey on *Medicago hispida* in San Diego, February 7, 1954, have been determined as *T. trifolii* (Monell). They are not the spotted alfalfa aphid and apparently represent a temporary establishment of the yellow clover aphid in California (R. C. Dickson, letter to author, April 23, 1958).

perial Valley (Deal, Dickson, and Reynolds, 1954). During the hot summer months, the infestations declined in the desert regions and then came back to moderate population levels in the fall (Dickson, Laird, and Pesho, 1955). Estimates of the damage in 1954 according to reports compiled by Lockwood

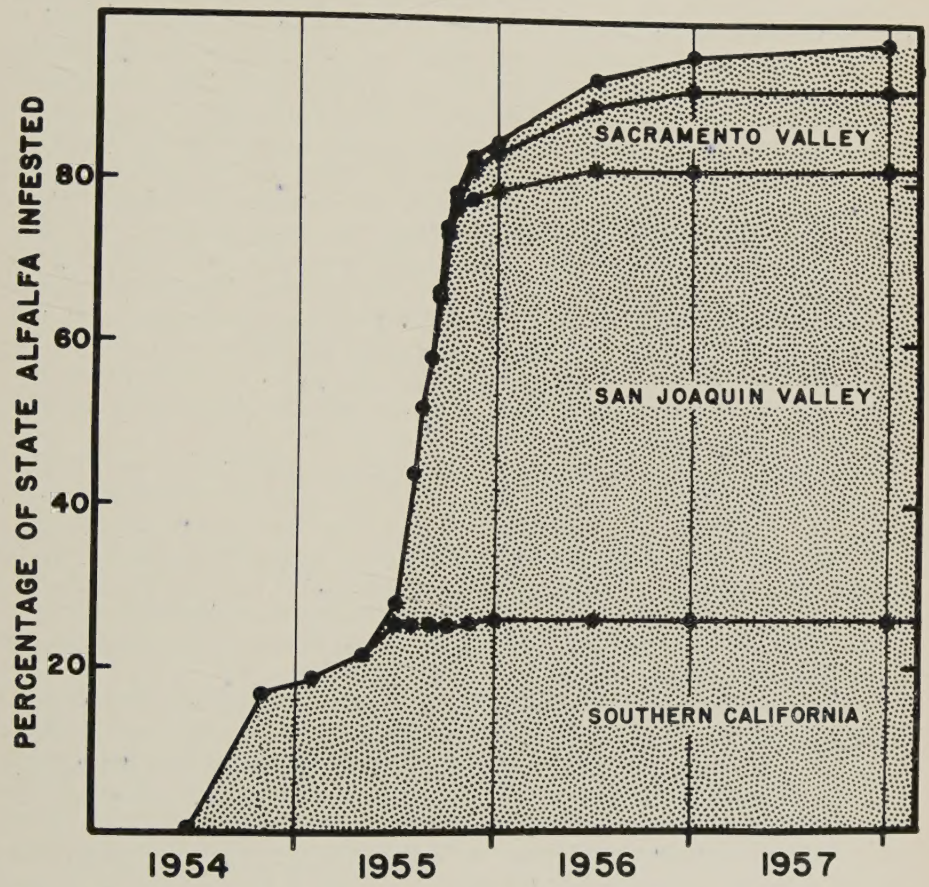

Fig. 4. The rate of spread of the spotted alfalfa aphid in California as indicated by the infested percentage of the total alfalfa acreage.

(1955) were $85,400 in Imperial County, $250,000 in Riverside County, $2,500 in San Diego County, and a state total of $337,900 (table 1).

During the winter of 1955, it was discovered that the Tehachapi Mountains offered no barrier to this aphid, for light infestations were located in the Magunden district near Edison in Kern County (fig. 7). Later another small infestation was found near Clovis in Fresno County (fig. 8). This opened the way for the spotted alfalfa aphid to spread throughout the major alfalfa-producing area of the state.

During the spring of 1955, heavy infestations developed in the desert regions. Over 125,000 acres were treated with insecticides during the month of

March in the Imperial Valley alone (Anonymous, 1955). Treatment was general for the aphid until mid-April, then diminished, but some treatments continued into June (Dickson, Laird, and Pesho, 1955; Dickson and Reynolds, 1955). At the same time, the aphid was spreading through the coastal areas of southern California (figs. 8 and 9). By the end of June, it is estimated that 97 per cent of the acreage in southern California was infested (fig. 4). In the coastal parts of southern California, aphid populations remained at subeconomic levels until August, when some fields were severely damaged in San Diego County. The next month other coastal districts reported damage.

In June, the Kern County and Fresno County infestations increased to high population levels and the aphid began its spread up the east side of the San Joaquin Valley (figs. 9 and 21). At the end of June, it occurred in low numbers at many points along Highway 99 as far north as Madera County.

In July, the spread continued in the same manner (fig. 10). Almost all of Kern County became infested, except the western districts, and treating was necessary in some fields in July. The Tulare County infestation extended from Dinuba to Tipton with the area around Visalia the most severely infested. In Kings County, infestations extended as far west as Armona. In Fresno County, it extended as far west as Kerman and over most of the section east of Highway 99.

In August of 1955, a large general infestation developed over most of the southern half of the San Joaquin Valley (figs. 11 and 12). Infestations were extremely varied, and severely damaged fields could be found in many counties. Chemical treatments were common in Kern, Kings, Tulare, and Fresno counties. The northern front of the spread continued to be along Highway 99. In late August when infestations were discovered in Stanislaus County they were confined to an area south of Modesto and extending about 2 miles west and 5 miles east of Highway 99.

Another major jump in distribution, across part of the Coast Ranges into the upper reaches of the Salinas Valley, also occurred in late August (figs. 12 and 23). This opened the way for the aphid to spread through the central California coastal valleys. It appeared at the time of the discovery of the aphid in San Luis Obispo County that this large jump was associated with the movement of sheep from the Antelope Valley of Los Angeles County. This is a distance of approximately 200 miles.

The spotted alfalfa aphid made another spectacular jump in its spread to the extreme northern portion of the Central Valley (fig. 13). In early September, nearly all of Tehama County was found to have a general light infestation. The heaviest infestations appeared to center around Gerber. This area is approximately 185 miles north of the previous known infestations. Earlier intensive surveys throughout the Sacramento Valley had not revealed any infestations.

In September, the infestations continued to spread in the San Joaquin and coastal valleys. Scattered infestations appeared in new districts in the Sacramento Valley (fig. 14). By the end of September, it is estimated that 86 per cent of the San Joaquin Valley's and 48 per cent of the state's alfalfa acreage was infested. During this month, Tehama, San Joaquin, Monterey, Santa Clara, Placer, and Yuba counties were found to be infested for the first

time. It is of interest that the first two infestations on the west side of the San Joaquin Valley north of Kings County (figs. 13 and 22), were on or near the two major cross-state highways in this area. The Los Banos infestations were found on Highway 152 and the Carbona infestations were about 3 miles south of Highway 50.

During October and November, the spotted alfalfa aphid continued its spread in most areas (figs. 15 and 16). October was a warm month and was favorable for aphid increase and spread. Control measures were necessary in many areas that had been infested earlier. In the San Joaquin Valley, the aphid now appeared north and south from Los Banos on the West Side along Highway 33. The infestations at Gustine, Dos Palos, and Firebaugh were very light and no chemical treatments were necessary. In the Sacramento Valley, aphid populations developed at scattered points, particularly in the eastern half of the valley. In the coastal areas, the infestations had spread along Highway 101 north in Monterey County as far as San Ardo and south through San Luis Obispo County into the northern part of Santa Barbara County. Another evidence of the ability of the spotted alfalfa aphid to spread, was an infestation on Santa Catalina Island discovered on November 3. This island is 22 miles off the southern California coast. During October, Santa Barbara, Sacramento, Solano, Butte, Glenn, and Shasta counties were reported infested for the first time. In November, the central coastal counties of San Benito, Alameda, Contra Costa, and Santa Cruz were found infested (fig. 16).

By the end of 1955, 33 California counties had been found to be infested. All of the southern California, 95 per cent of the San Joaquin Valley's, 44 per cent of the Sacramento Valley's, and 85 per cent of the total state alfalfa acreage was infested by the spotted alfalfa aphid (fig. 4). While the aphid was spreading in California, it was also spreading in other areas. In addition to California, it occurred in 13 other states including Arizona, Nevada, Idaho, New Mexico, Utah, Texas, Oklahoma, Colorado, Kansas, Nebraska, Louisiana, Arkansas, and Missouri (fig. 17).

Despite the fact that the total amount of damage was significantly reduced by chemical control measures, the Bureau of Entomology of the State Department of Agriculture estimated 1955 crop losses to be $9,330,000 and the cost of control to be $3,525,000.

In the first half of 1956, the spotted alfalfa aphid made additional local increases in distribution (fig. 18). The spread was now evident east of the Sierra Nevada, although it appeared that these infestations had developed the previous fall. By the end of June, the entire state south of Sacramento was infested. In the Sacramento Valley, 76 per cent of the alfalfa acreage was judged to be infested and in the state as a whole, 93 per cent of the acreage was infested (fig. 4).

By the end of the year (fig. 19), the alfalfa acreage of the entire Central Valley, the coastal districts as far north as Rutherford in Napa County, and east of the Sierra Nevada as far north as Benton in Mono County were infested. The north coast counties and the transmontane northern counties were still uninfested. These counties contain about 4 per cent of the state's alfalfa acreage.

The 1956 losses in southern California appeared to have been reduced, as compared with 1955, through the alert action of the growers and increased activity of predators. In central and northern California, spotted alfalfa aphid damage was more widespread. In some areas, for example Tulare County, the impact of the aphid was reduced by fungus disease and predators. In other areas where little or no damage occurred in 1955, for example western Fresno County and Monterey County, damage was moderate to severe. The State Bureau of Entomology has estimated that $5,325,000 was spent for control and the crop losses were $5,275,000 in 1956 (table 1).

The spread across the nation continued in 1956 (fig. 19). In March, the spotted alfalfa aphid was discovered at Gainesville, Florida, and later in Mississippi. In July, five more states (Georgia, Illinois, South Carolina, Kentucky, and North Carolina) and in August, four more states (South Dakota, Virginia, Iowa, and Tennessee) were found infested. In September, Minnesota and West Virginia; in October, Indiana and Alabama; and finally, Wisconsin reported the aphid. Thus, it was then found in 30 states and probably occurred in others.

In the Midwest and Southwest sections of the United States infestations developed to economic levels in Kansas, Oklahoma, Texas, and southwestern Missouri in the spring of 1956. The situation was particularly acute in south-central Oklahoma where many stands of alfalfa were lost. Texas reported the aphid to be two to three times worse than in 1955. Drought aggravated the damage in many areas. In the summer and fall, populations occurred in damaging numbers in Colorado, Missouri, Nebraska, Kansas, New Mexico, and Louisiana. In the areas north of these states and east of the Mississippi, populations were lower and damaging infestations were scattered or absent. In Arizona, the general infestations were lighter in the spring than in 1955, and heavier in September.

During the spring of 1957, additional spread in California occurred in the north coastal area with Lake and Mendocino counties being reported infested for the first time. The first transmontane record of the spotted alfalfa in northern California was made with its discovery in Susanville on June 21. Later in the summer, infestations were found in Siskiyou County as far north as Montague.

Thus by the end of 1957 (fig. 20), 42 out of the 47 alfalfa-producing counties (that is, those with over 100 acres of commercial alfalfa) in California were reported to be infested. All of the Central Valley and all of southern California were infested. The only areas in which the aphid did not occur were outlying districts on the north coast and in parts of Siskiyou, Modoc, and Lassen counties. At that time 97.5 per cent of the state's alfalfa acreage was judged to be infested.

The spotted alfalfa aphid is now considered to be one of the ten most important insect pests in California. Alfalfa growers have recognized the importance of this aphid and, in general have reduced the damage through chemical controls and improved cultural practice. The activity of native predators and introduced parasites, and the influence of weather have also ameliorated the general situation. Nevertheless, the estimate of damage and cost of control was $9,705,000 in 1957.

Fig. 5. Reported infested localities for the spotted alfalfa aphid as of June 30, 1954. (1) San Diego, February 7, 1954. This record was later determined to be *Therioaphis trifolii* (Monell). (2) Bard, June 17, 1954. (3) Orita, June 23, 1954. (4) Blythe, mid-June, 1954.

Fig. 6. Known infested localities for the spotted alfalfa aphid as of October 31, 1954. (1) Nuevo, September 22, 1954. (2) Coachella Valley, October 1, 1954. (3) Borrego, October 18, 1954.

Fig. 7. Known infested localities for the spotted alfalfa aphid as of January 31, 1955. (1) Newberry, November 7, 1954. (2) Irvine, December 8, 1954. (3) Needles, December 10, 1954. (4) La Habra, December 13, 1954. (5) 6 miles southeast of Lancaster, December 14, 1954. (6) Hinckley, December 30, 1954. (7) Edison, January 25, 1955.

Fig. 8. Known infested localities for the spotted alfalfa aphid as of April 30, 1955. (1) Santa Susana, February 8, 1955. (2) 3 miles southeast of Clovis, April 13, 1955. (3) 7 miles northwest of Lancaster, April 27, 1955.

Fig. 9. Known infested localities for the spotted alfalfa aphid as of June 30, 1955. (1) 2 miles southeast of Selma, May 3, 1955. (2) Berenda, June 7, 1955. (3) McFarland, June 8, 1955. (4) 9 miles east of Hanford, June 9, 1955. (5) 14 miles south of Poplar, June 9, 1955. (6) 1 mile south of Visalia, June 30, 1955.

Fig. 10. Known infested localities for the spotted alfalfa aphid as of July 31, 1955. (1) 7 miles east of Gregg, July 25, 1955. (2) Weldon, July 30, 1955. (3) 2 miles northwest of Merced, July 31, 1955.

Fig. 11. Known infested localities for the spotted alfalfa aphid as of August 15, 1955. (1) 5 miles northwest of Chowchilla, August 8, 1955. (2) Califa, August 8, 1955. (3) Livingston, August 9, 1955.

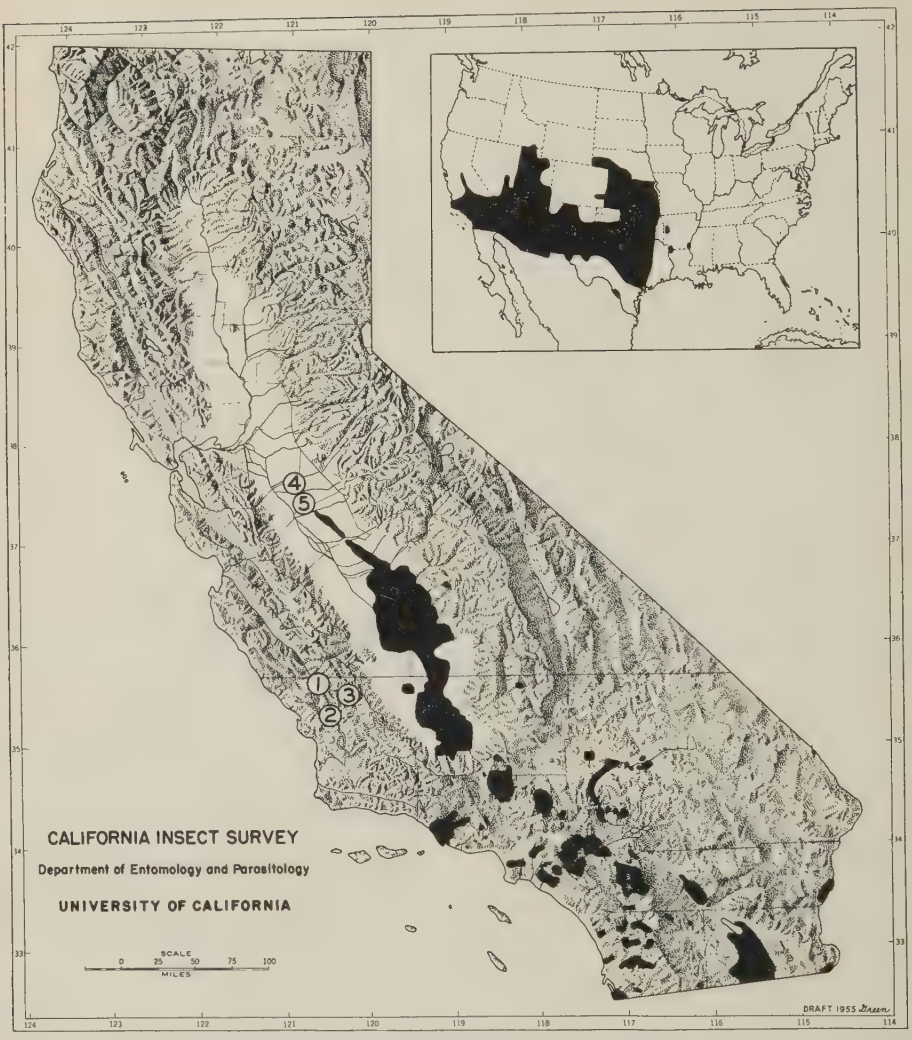

Fig. 12. Known infested localities for the spotted alfalfa aphid as of September 1, 1955. (1) San Miguel, August 19, 1955. (2) Atascadero, August 24, 1955. (3) Shandon, August 24, 1955. (4) Modesto, August 25, 1955. (5) Turlock, August 26, 1955.

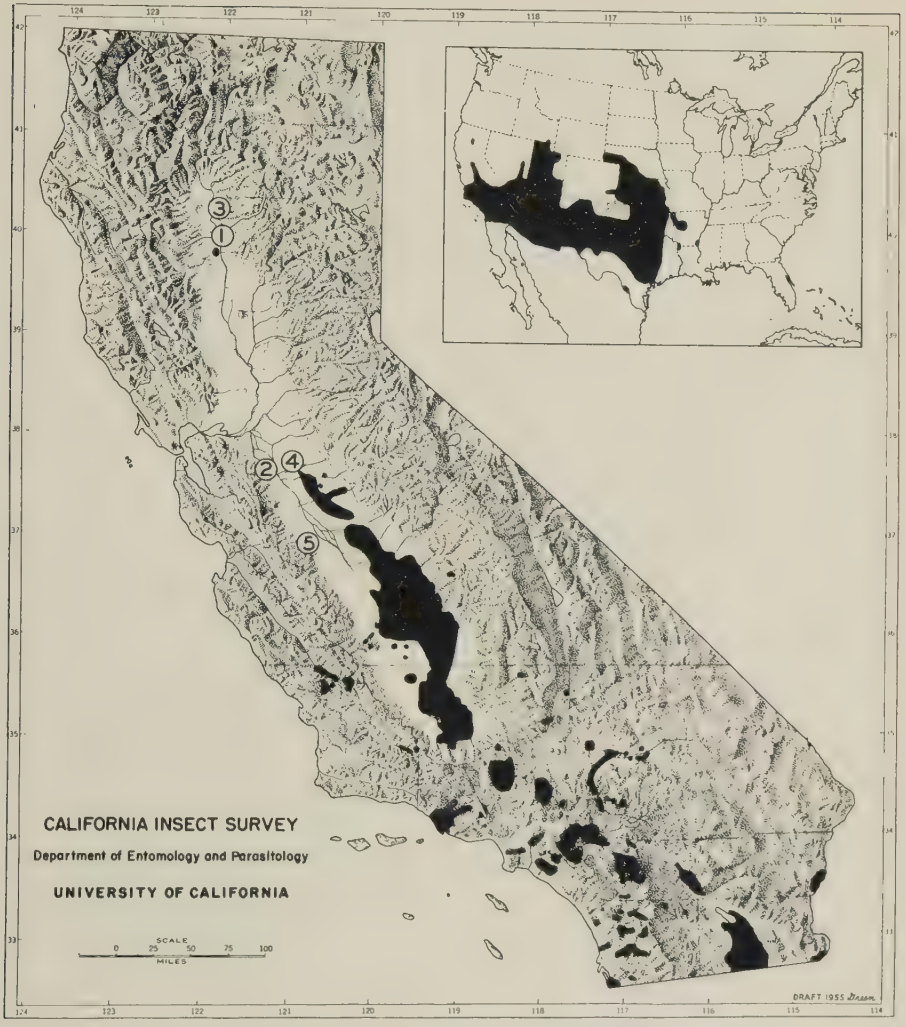

Fig. 13. Known infested localities for the spotted alfalfa aphid as of September 15, 1955. (1) Gerber, September 2, 1955. (2) Carbona, September 6, 1955. (3) 4 miles east of Red Bluff, September 7, 1955. (4) 1.5 miles southeast of Manteca, September 10, 1955. (5) Los Banos, September 14, 1955.

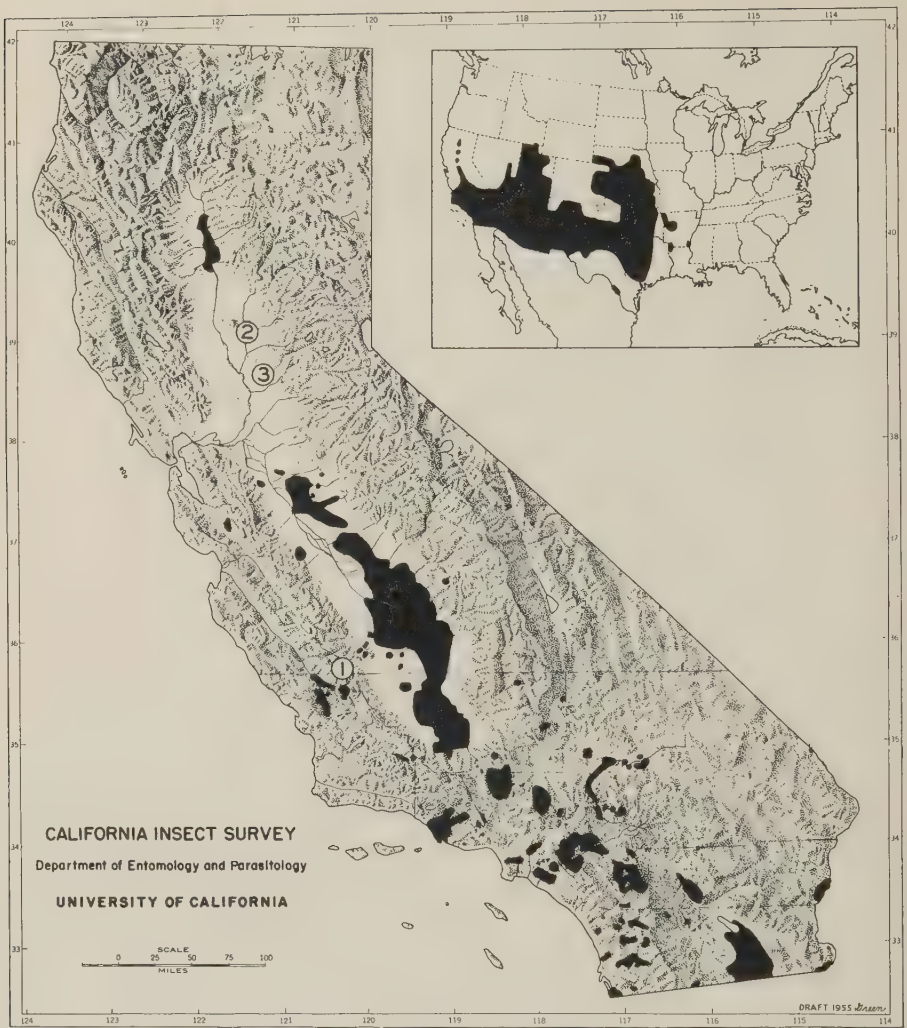

Fig. 14. Known infested localities for the spotted alfalfa aphid as of September 30, 1955. (1) Parkfield, September 16, 1955. (2) Marysville, September 28, 1955. (3) Roseville, September 30, 1955.

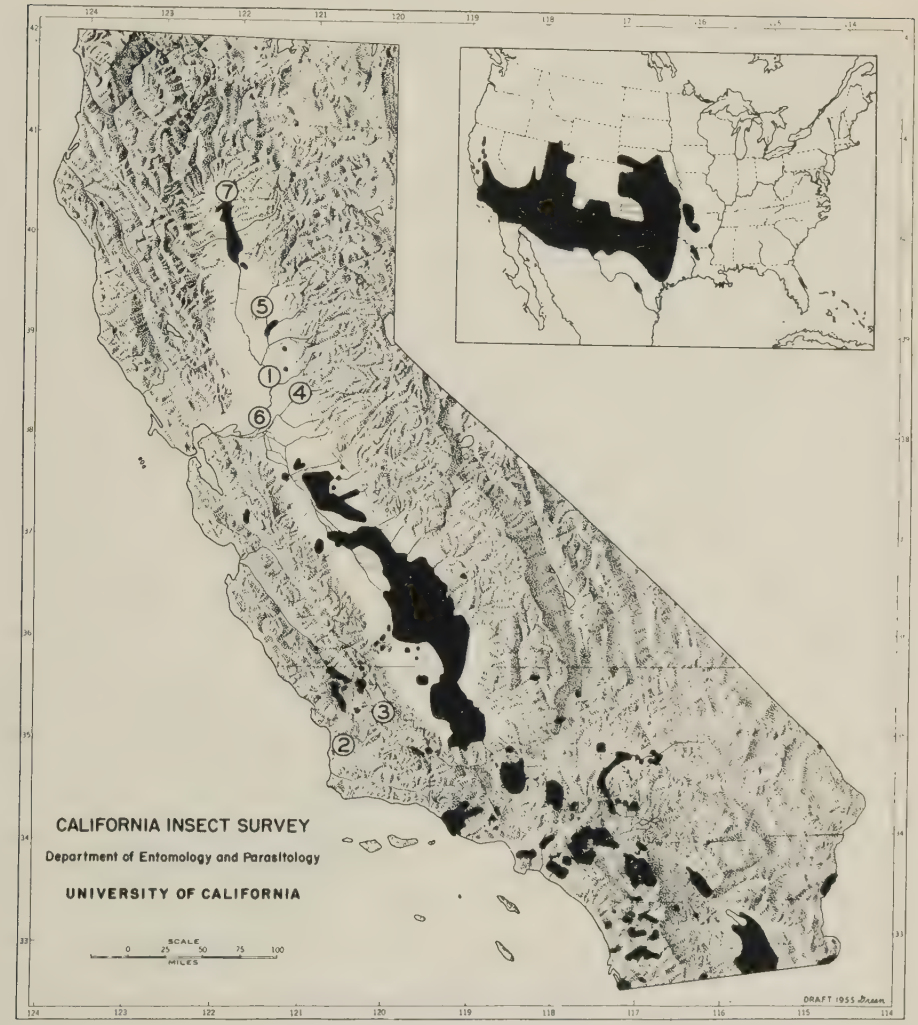

Fig. 15. Known infested localities for the spotted alfalfa aphid as of October 15, 1955. (1) Elverta, Antelope, and North Sacramento, October 5, 1955. (2) Nipomo, October 5, 1955. (3) Carrizo Plain, October 5, 1955. (4) Fairoaks, October 6, 1955. (5) 2 miles southeast of Gridley, October 10, 1955. (6) Ryer Island, October 13, 1955. (7) Cottonwood, October 14, 1955.

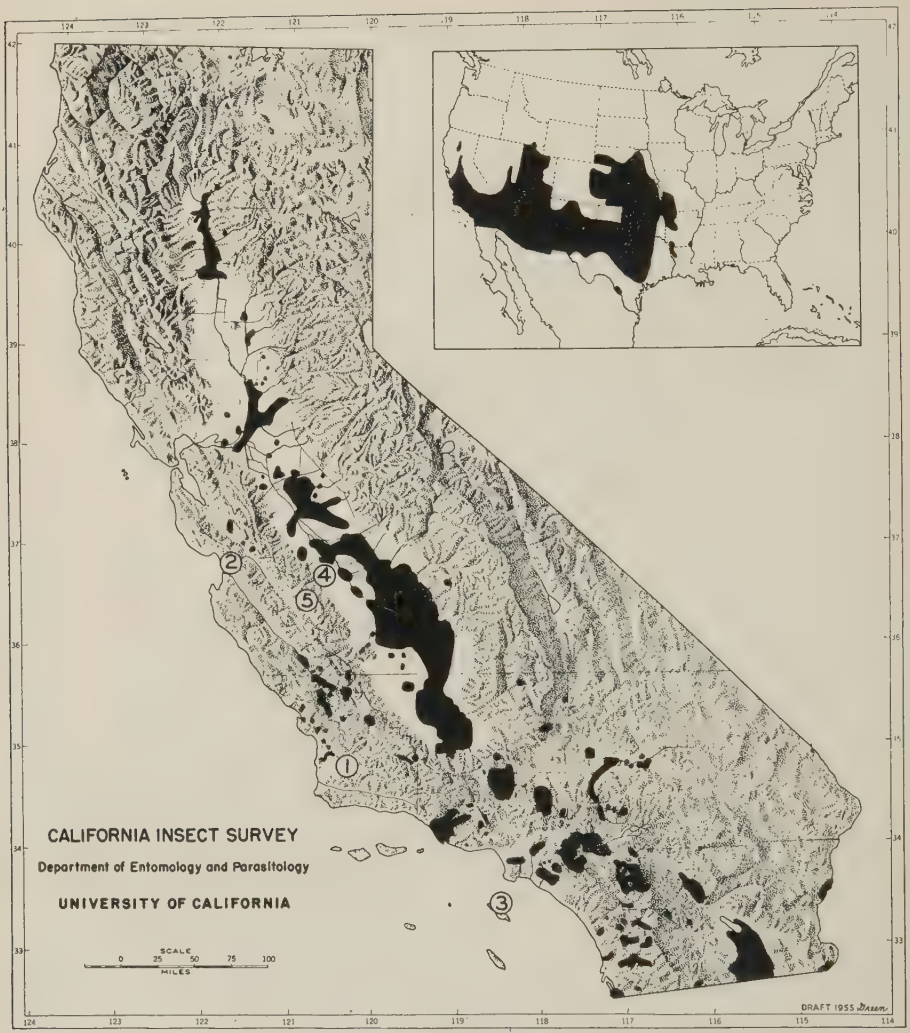

Fig. 16. Known infested localities for the spotted alfalfa aphid as of November 15, 1955. (1) Sisquoc, October 20, 1955. (2) Watsonville, November 1, 1955. (3) Avalon, November 3, 1955. (4) Firebaugh, November 9, 1955. (5) Panoche, November 9, 1955.

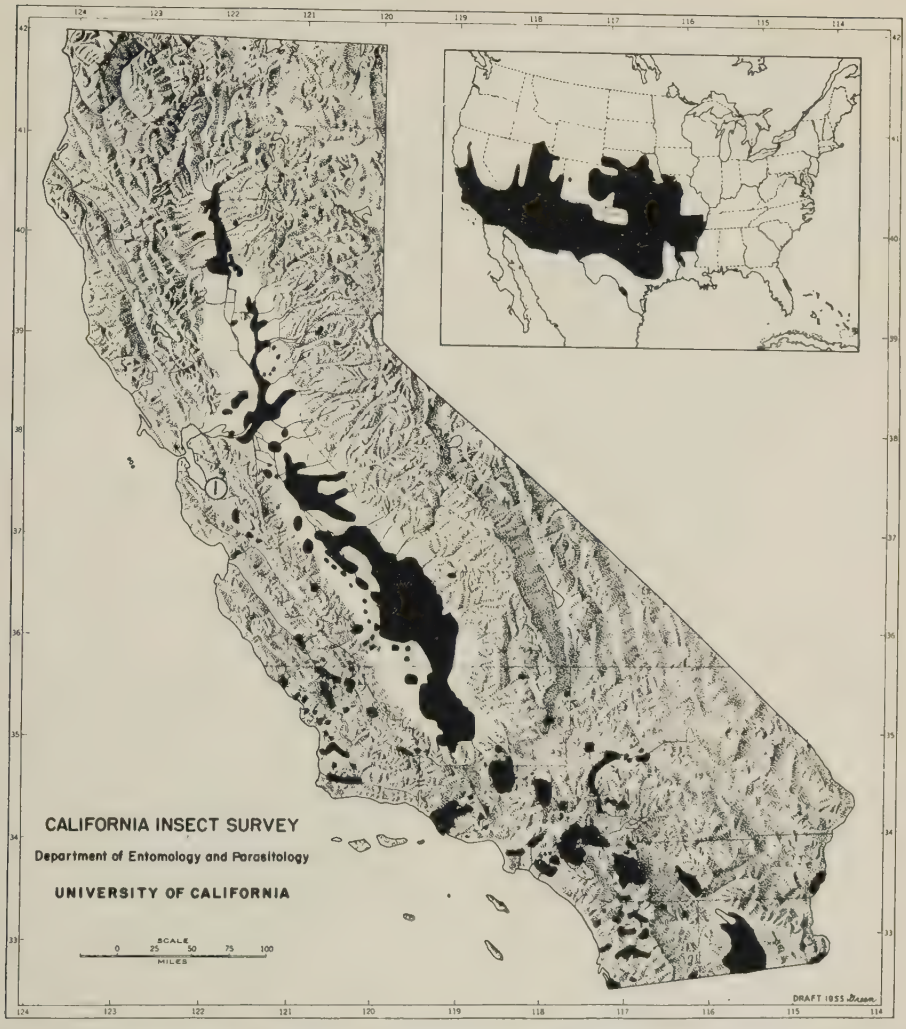

Fig. 17. Known infested localities for the spotted alfalfa aphid as of December 31, 1955. (1) Irvington, November 23, 1955.

Fig. 18. Known infested localities for the spotted alfalfa aphid as of June 30, 1956. (1) Olancha, March 1, 1956. (2) Independence, April 3, 1956. (3) 6 miles south of Big Pine, June 22, 1956.

Fig. 19. Known infested localities for the spotted alfalfa aphid as of December 31, 1956. (1) Ione, September 21, 1956. (2) Benton, September, 1956. (3) Rutherford, October 24, 1956. (4) San Andreas, December 12, 1956.

Fig. 20. Known infested localities for the spotted alfalfa aphid as of December 31, 1957. (1) 5 miles east of Hopland, March 27, 1957. (2) Susanville, June 21, 1957. (3) Hat Creek and Fall River Valley, August 10, 1957. (4) Montague, September 24, 1957. (5) Scott Valley, October 1, 1957. (6) 4 miles northwest of Placerville, December 19, 1957.

METHODS OF SPREAD AND DISPERSAL

The spotted alfalfa aphid has utilized most of man's means of transportation in accomplishing its spread. In addition, its own flight as modified by the prevailing patterns of air currents has helped to determine the path of its spread.

Dispersal. Local field to field dispersals are made largely by the alates. Laboratory and field data of Paschke (1958) indicate that the primary factor responsible for the production of alates is the population density or "crowding" of the developing aphids. Hence a heavily infested field will produce large numbers of alates which then disperse to other fields when the proper weather conditions prevail. Large numbers of alates may occur at any time of the year, but the greatest numbers will be associated with the highest aphid

TABLE 2
DISPERSAL OF ALATES AS INDICATED BY THE STICKY-BOARD SAMPLING METHOD; AUGUST, 1955

Date	Aphids recovered per day			
	Area A	Area B	Area C	Area D
20	2	2	0	0
21	5	0	1	0
22	6	3	0	0
24	8.5	2.0	0.5	0.5
26	27.0	37.5	1.5	8.5
27	176.0*	11	39*	6
29	6.0	3.0	1.5	0.0

* The field was cut immediately to the north of sampling site prior to count on this date and in the remainder of the field the next day.

populations. Therefore, the greatest dispersal and spread will occur from March to mid-June and again in the fall in the Colorado Desert, from May to November in the Antelope and Central valleys, and in late summer in the coastal areas. The rate of spread of the spotted alfalfa aphid has followed this pattern very closely.

The dispersals of the aphid from alfalfa fields will be at the highest level at the time source alfalfa fields are mowed and when aphid populations are high. Table 2 presents data obtained by placing "sticky boards" at plant height in an alfalfa field approaching maturity. On August 19, the alate aphid population was low in all areas and very little flight occurred. The aphid counts in the alfalfa on this date were 0.5 alate per stem in area A, 0.2 per stem in area B, and 0.01 in areas C and D. By August 22, the alate population levels were 1.1 per stem in area A, 0.6 per stem in area B, 0.04 in area C and 0.01 in area D. On August 25, the alate population levels were 3.1 per stem in area A, 1.7 in area B, 0.1 in area C, and 0.06 in area D. From these data and the data in table 2, it can be seen that dispersal increased as the alate population increased and then jumped to high levels as the field was cut.

Field observations indicate that high populations of alates will infest other fields to a potentially economic level ½ mile away even though separated by other suitable alfalfa. One such observation was made in an isolated alfalfa

TABLE 3

NUMBER OF ALATE SPOTTED ALFALFA APHIDS PER STEM AT VARIOUS DISTANCES FROM AN UNTREATED END OF A FIELD;* REEDLEY, 1955

Date	Untreated area	Distance from untreated area (feet)																	
		80	280	440	640	800	960	1,120	1,280	1,480	1,640	1,840	2,000	2,160	2,320	2,520	2,680	2,840	3,040
Sept. 27	1.5	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00
Sept. 28	3.7	0.25	0.00	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.10	0.00	0.05	0.00	0.15	0.00
Sept. 30	1.5	0.6	0.2	0.1	0.0	0.2	0.15†	0.1	0.2	0.0†	0.1	0.00	0.10	0.0	0.1	0.2†	0.1	0.1	0.2
Oct. 3	5.6	2.1	0.7	0.9	0.4‡	0.7	0.4	0.3	0.4	0.4	0.8	0.4	0.5‡	2.0	0.2	0.1	0.4	0.4	0.5‡
Oct. 7	...	1.8	1.7	1.5	0.6	0.6	0.1	0.4	0.4	0.2	0.5	0.6	0.4	1.5	0.5	0.3	0.2	0.5	1.1
Oct. 10	8.9	5.4	3.6	2.7	2.5	2.2	0.8	1.1	0.7	0.9	0.6	1.4	1.4	2.7	1.2	0.8	0.9	0.5	0.4
Oct. 14	6.8	4.6	2.6	3.0	2.3	2.1	1.4	2.5	1.5	2.5	1.9	1.4	1.0	2.5	1.4	1.0	1.0	1.7	0.8

* The main portion of the field had been treated with various chemicals and formulations on September 24, reducing the aphid population to a low level.
† Insecticidal treatment was still probably affecting establishment of alates as late as September 30.
‡ Insecticidal treatment was still probably affecting establishment of alates as late as October 3.

field in Fresno County in 1955 (table 3). An area of about 20 acres in the south end of this large field was left untreated at the time an insecticide trial reduced the aphid population to low levels in the remainder of the field. The population in the untreated area was unevenly dispersed. Samples indicated total population levels of 9.1 per stem on September 26, 42.5 per stem on September 28, and 150 per stem on October 10. A large number of alates were produced in this area and they moved into the treated section of the field. In September, the production of alates was relatively low and the residual effects of the insecticides were still reducing the establishment of dispersing alates. On October 3, the data indicate that the alates had moved in significant numbers a distance of about 80 feet into the adjacent area. By October 7, significant increases in alates were observed a distance of 440 feet into the area which had been treated earlier. By October 10, the distance had increased to 800 feet. On October 14, the picture became confused by the production of alates within the treated area, but there is some evidence that dispersing alates from the untreated areas contributed significantly to the population over ¼ mile into the treated area.

When other suitable alfalfa does not intervene, the distances of such dispersals is much greater. Dickson[5] states that he has observed alate *Therioaphis maculata* landing on potted alfalfa plants about 70 miles from the nearest planting of alfalfa. Such movements undoubtedly account for a large part of the spread of the spotted alfalfa aphid, for only one female need survive to establish the species in a new area. On the other hand, it is impossible to separate such movements from spread brought about by man, and some observations indicate air currents may reduce spread.

Spread with Commerce. The spotted alfalfa aphid is very hardy. It easily survives without food for 12 hours at 30°C. Paschke (1959) presents data indicating an LD_{50} of 5.7 days when starved 16 hours a day at 24°C. This hardiness means that it can be inadvertently distributed by automobiles, trucks, trains, airplanes, farm machinery, and on or in clothing. Several such instances were observed, as the spread of the spotted alfalfa aphid was traced, of jumps of 25 to 200 miles which were directly associated with custom balers, truckers, feed-lots, and movements of livestock.

The impact of commerce on the spread of *Therioaphis maculata* is also seen in the routes it has taken in northern California. In the San Joaquin Valley, its spread closely paralleled the main north-south highway (U. S. No. 99). In July and August, this was especially evident (fig. 21) and many of the first county records of the aphid were taken adjacent to this highway. It is also significant that the first records on the west side of the San Joaquin Valley north of Kings County were adjacent to the two main east-west highways in this area (fig. 13). After the aphid became established in the Los Banos area, it then spread north and south along Highway 33 on the west side of the valley (fig. 22). Another indication of the effect of these major transportation routes is seen in the coastal area. After the aphid became established in the northern part of San Luis Obispo County it then spread north and south along Highway 101 (fig. 23). As a result, the first infestations found in Santa Barbara County were at the northern edge.

[5] Dickson, R. C. Letter to author, June 6, 1956.

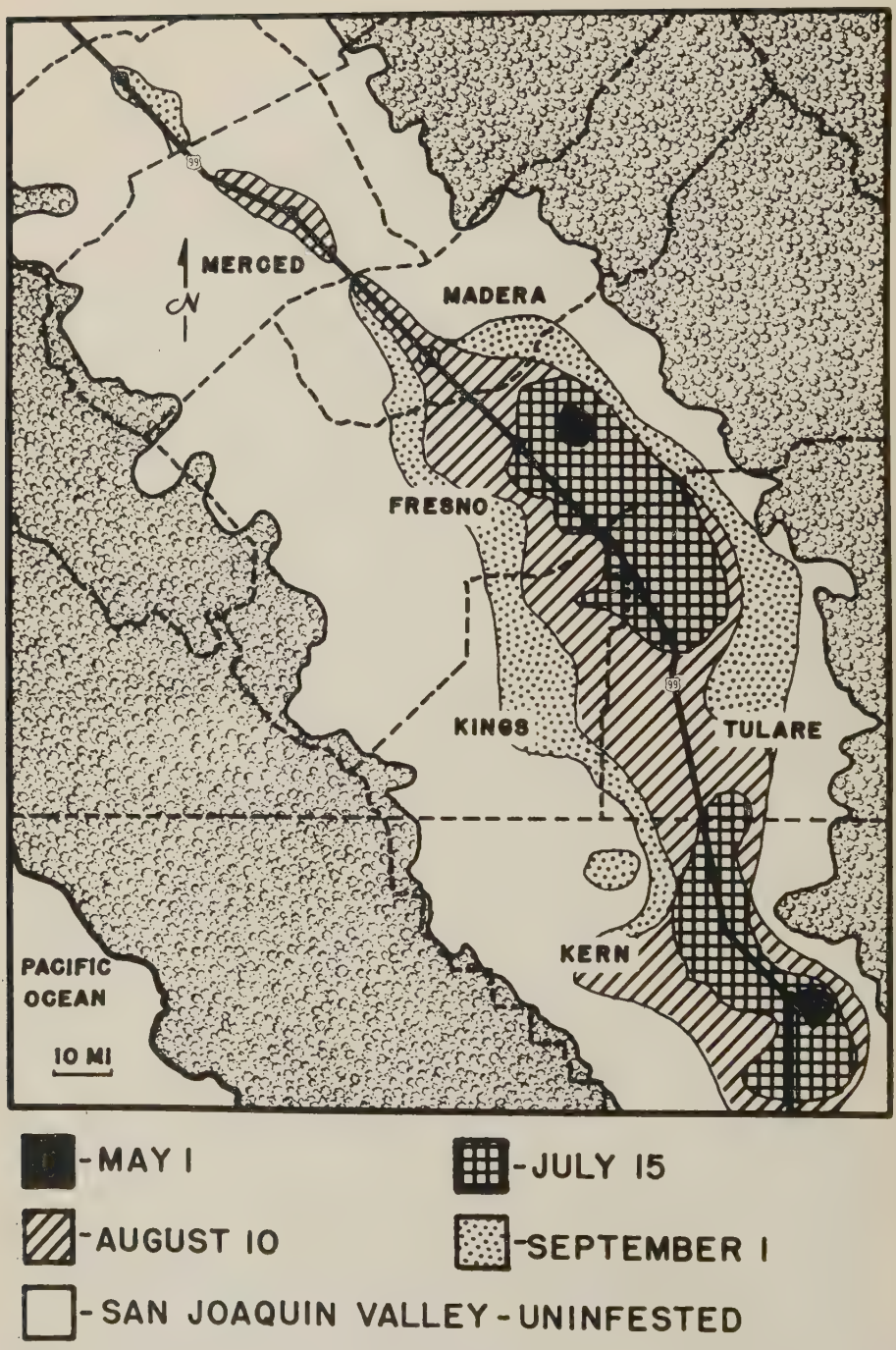

Fig. 21. Spread of the spotted alfalfa aphid in the San Joaquin Valley of California from May 1 to September 1, 1955. County boundaries are indicated by dashed lines.

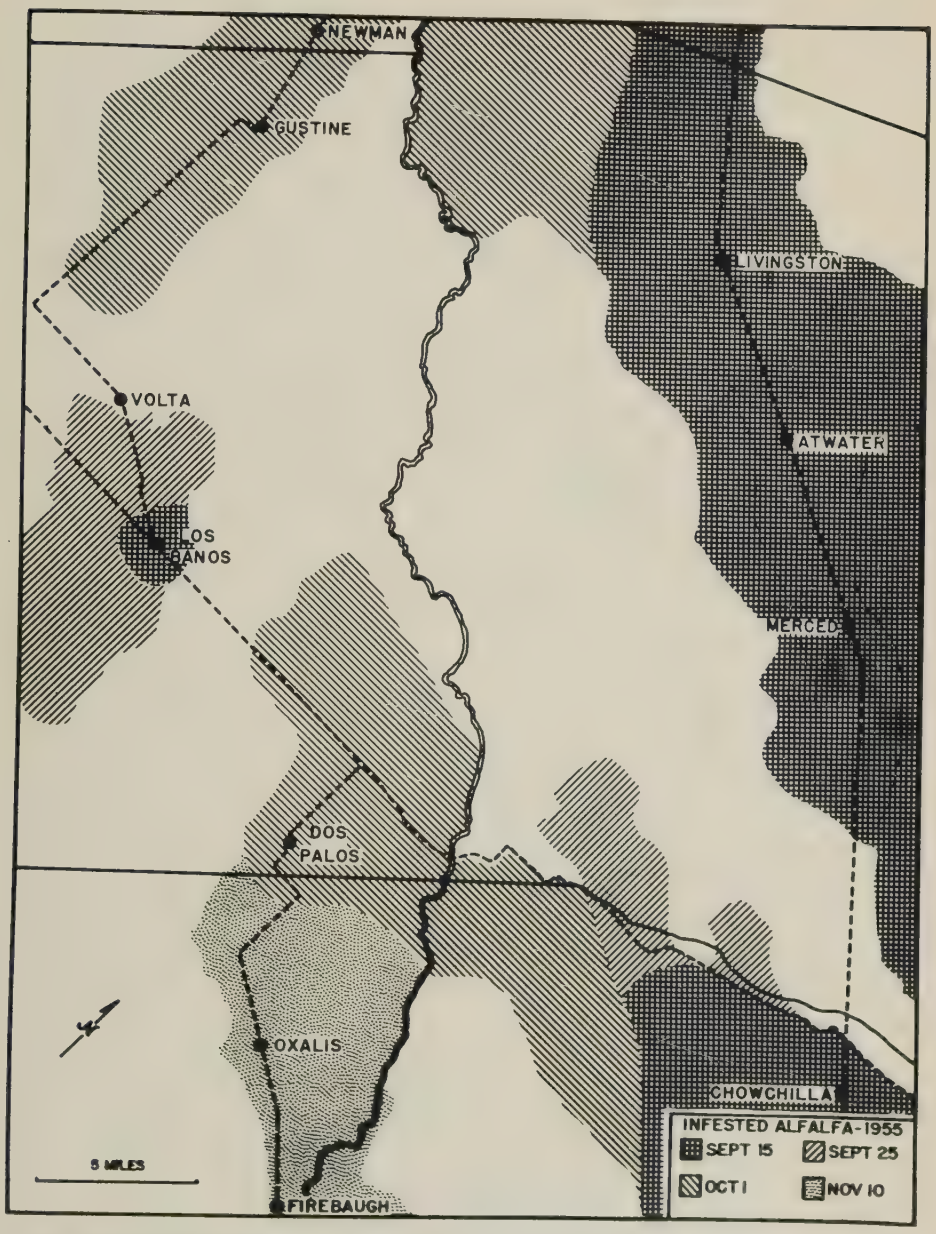

Fig. 22. Spread of the spotted alfalfa aphid in the central portion of the San Joaquin Valley from September 15 to November 10, 1955. Major highways are indicated by dashed lines, county boundaries by solid lines.

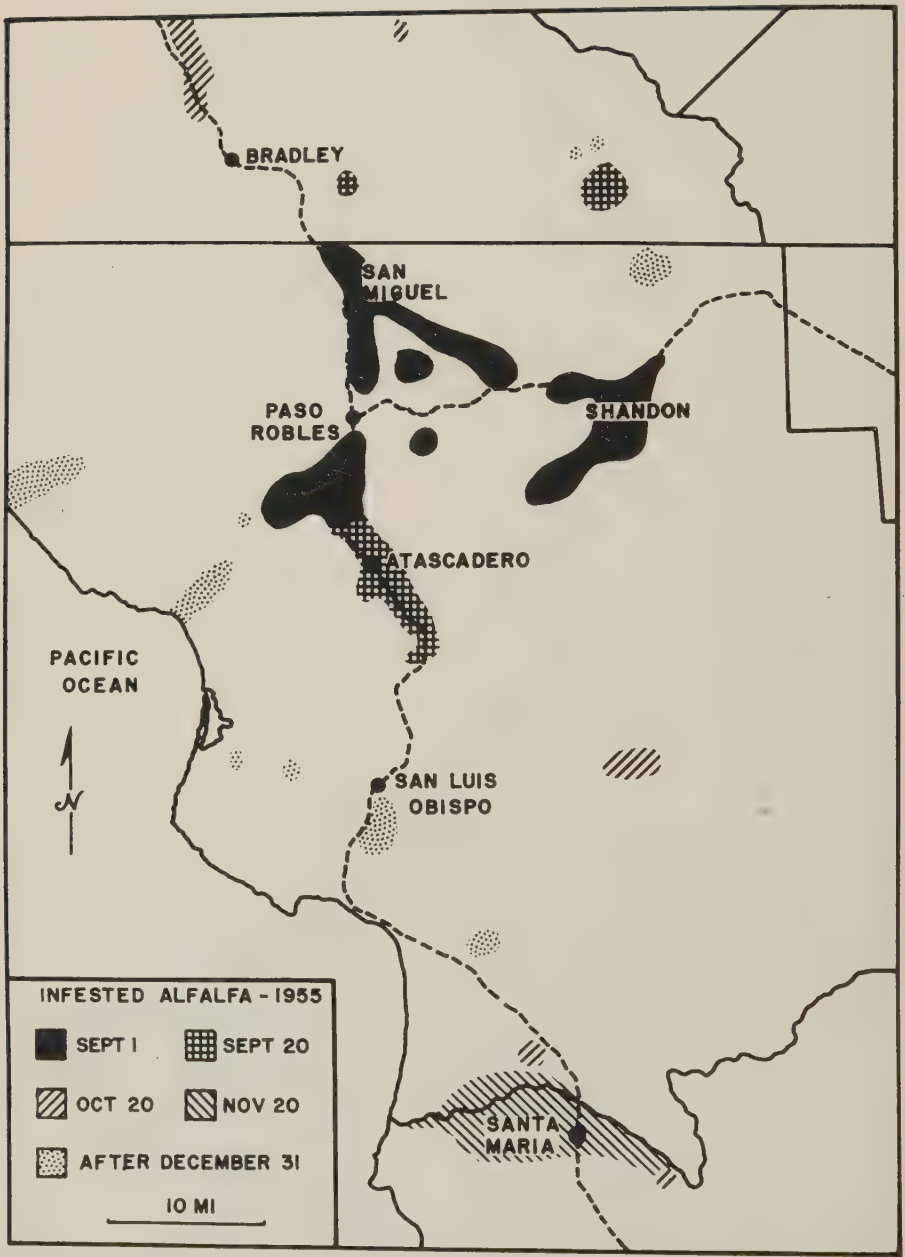

Fig. 23. Spread of the spotted alfalfa aphid in central coastal California from September 1 to December 31, 1955. Major highways are indicated by a dashed line.

Effects of Air Currents. During the summer months in northern California, with the great North Pacific Anticyclone dominating the climate, the main influx of air into the Central Valley passes through the Golden Gate and other low-lying areas. This stream of air splits; some air goes north into the Sacramento Valley and some south into the San Joaquin Valley (Holzworth, 1957). This pattern of prevailing winds undoubtedly had much to do with the pattern of the spotted alfalfa aphid spread in the Central Valley. The air currents have two different effects; one is to deter spread and the other is to assist it. In general, aphids will take off in flight during the daylight hours when the wind speed is less than 4 miles per hour and the temperature is over 55°F. Hence aphid movements will be restricted to limited times of the day by wind and temperature conditions. When the aphids are in flight the direction of the wind will determine the direction of their spread and dispersal.

Combined Commerce and Air Currents. The patterns of dispersal in the San Joaquin Valley in 1955 would appear to be a combination of spread resulting from man's activities and the effects of air currents. Until mid-June aphid populations were low in all areas and little spread occurred. In late June and early July populations increased to high levels and the spread developed along Highway 99 and east of this highway (fig. 21). An examination of table 4 suggests the explanation for this pattern. In June and July, 57.3 per cent of the favorable time for aphid flight the wind was from the northwest, north, or northeast, while for only 14.2 per cent of the time was it from the southeast, south, or southwest. In late July and early August the association with traffic on Highway 99 was especially conspicuous. In August, wind from the south during favorable flight periods increased significantly, and this is reflected in spread west of Highway 99 (fig. 21).

After the aphid reached the west side via commerce in late September, the southerly winds were as important as the northerlies in distributing the aphids. Westerly currents, such as those described by Smith, Gail, and Isaak (1956), and updrafts along the foothills also contributed to the rapid infestation of the east side.

In a similar way the spread northward in the Salinas Valley (fig. 23) was delayed by the winds that prevail here. On the other hand, the prevailing wind may favor the spread. McCorkindale[6] describes such a situation in the Antelope Valley.

IMPACT ON ALFALFA PRODUCTION

Costs of insect control in alfalfa production under California conditions has been such a low and variable amount that they were not included in most cost analyses prior to the advent of the spotted alfalfa aphid (Stanford, *et al.*, 1954). In the Dos Palos area, an area which has had a more severe alfalfa insect problem than most of the San Joaquin Valley, the average required number of insecticide treatments per acre during the third, fourth, and fifth cutting period in the years 1947 to 1951 was 0.29 (based on 65,315 acres under supervised control). Most of these treatments were for the control of the alfalfa caterpillar, *Colias philodice eurytheme* Boisduval.

[6] McCorkindale, L. D. Letter to author, January 23, 1956.

TABLE 4

DIRECTION OF WINDS AT LESS THAN FOUR MILES PER HOUR DURING THE DAYLIGHT HOURS WITH AN AIR TEMPERATURE OVER 55° F; FRESNO, CALIFORNIA, 1955*

Months	Favorable flight conditions		Wind direction (estimated hours per month)																	
	Days	Hours	Calm	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
January	3	8	0	3	0	0	0	3	0	0	0	0	0	0	0	0	2	0	0
February	10	40	0	5	13	5	0	0	0	0	1	0	2	1	8	5	0	0	0
March	10	30	0	0	0	0	0	0	0	2	6	8	7	0	0	0	6	1	0
April	7	34	4	0	0	3	0	0	0	0	0	0	0	4	0	5	6	0	12
May	16	104	6	0	9	15	0	3	9	3	6	0	3	0	6	0	14	12	18
June	17	99	3	3	6	16	0	6	6	6	0	0	0	6	6	6	6	19	10
July	25	112	21	12	6	6	0	0	0	0	0	0	6	12	6	0	0	28	15
August	29	197	32	9	0	0	6	6	12	36	12	9	15	12	6	6	0	6	30
September	19	129	15	6	0	3	0	6	0	18	24	6	6	24	0	6	9	6	0
October	19	137	24	18	0	6	0	6	0	0	0	12	11	5	0	12	21	5	17
November	14	66	3	10	0	3	0	2	0	6	0	2	5	9	13	12	1	0	0
December	4	17	7	0	0	0	0	0	0	0	0	6	0	4	0	0	0	0	0

* Compiled from the hourly temperature records and the 6-hourly observations for wind (Local Climatological Data, Fresno, California).

Chemical treatments for pest control greatly changed the cost of alfalfa production after the spotted alfalfa aphid increased to economic levels. As can be seen in table 5, the number of treatments in the heavily infested parts of the San Joaquin Valley was about three per acre. Many growers averaged over $10 per acre for control measures. In spite of these treatments, yields were reduced. The annual alfalfa hay yield estimated by the California Crop

TABLE 5

CHEMICAL TREATMENTS APPLIED FOR THE CONTROL OF THE SPOTTED ALFALFA APHID ON SELECTED RANCHES IN THE CENTRAL VALLEY OF CALIFORNIA

Area	Year	Acreage of alfalfa	Treatments per acre	Percentage of acreage				
				Not treated	Treated once	Treated twice	Treated three times	Treated over three times
Lower Sacramento Valley	1956	435	1.11	8.5	72.2	19.1	0.0	0.0
	1957	504	2.01	10.9	10.7	48.8	25.6	4.0
Firebaugh	1956	1,918	1.89	....	....	....	....	....
Stanislaus County (east side)	1957	269	0.60	66.9	16.0	12.3	0.0	4.8
Wasco	1956	404	2.90	0.0	0.0	38.6	40.4	21.0
	1957	366	2.42	0.0	31.1	0.0	64.5	4.4
Kern County	1956	7,673	3.3	0.0	0.0	17.9	56.0	26.0
Merced County	1956	1,561	2.4	...	...	...	...	...
	1957	2,583	3.5	...	...	...	...	...
Arvin	1955	265	1.9	0.0	41.5	28.3	30.2	0.0
	1956	270	4.5	0.0	0.0	7.4	7.4	85.1
	1957	266	2.8	0.0	20.3	15.0	45.9	18.8
Dos Palos	1956	1,966	3.2	0	0	37.7	21.1	41.2
	1957	3,050	3.1	3.2	16.1	12.9	20.8	47.3

and Livestock Reporting Service was 4.50 tons per acre in 1956—the lowest since 1949. Other factors undoubtedly contributed to this poor production but the spotted alfalfa aphid was a major factor.

Costs for increased insect control per treatment ranged from 65 cents to $4 per acre for materials and from 50 cents to $2.50 per acre for application (table 6). If we assume a previous average yield of 7 tons per acre, a basic total production cost of $18 per ton, and a total annual cost of control of $10 per acre, the increased cost of production per ton will be $1.43 if there is no decrease in yield. However, if yields drop 1 ton per acre in spite of treatments, the total cost of production per ton will increase $3.67. In some fields, uncontrolled infestations have reduced expected yields by over 50 per cent in one cutting. Another indication of the impact of the aphid is the change in the acreage of alfalfa and clovers treated by aircraft in California. This was esti-

TABLE 6

COSTS FOR SPOTTED ALFALFA APHID CONTROL—1955 APPLICATION*

Ground application with own sprayer:

Annual costs of maintenance, depreciation and interest on sprayer $98.75
Man labor and tractor cost per acre per application ..... $ 0.26

Total annual cost per acre (4 applications per year)
Acreage treated each application
30 acres ..... $ 4.33
60 acres 2.69
120 acres 1.86
200 acres 1.53

Ground application—contract:

Cost per acre per application—$1.00 to $1.50
Annual cost per acre for 4 applications—$4.00 to $6.00

Air application—contract:

Cost per acre per application—$1.25 to $2.25
Annual cost per acre for 4 applications—$5.00 to $9.00

Materials

Cost per acre per application—$0.65 to $4.00
Annual cost per acre for 4 applications—$2.60 to $16.00

* Prepared with the assistance of B. B. Burlingame, Extension Economist.

mated[7] at 224,100 in 1950. It dropped to 124,200 in 1951, then came back to 232,300 and 234,100 in 1952 and 1953 respectively. Most of this treatment was spider mite and lygus bug control on these crops grown for seed. In 1954, the treated acreage was over 410,500, in 1955 it was 1,125,500, in 1956 it was 1,594,300 and in 1957 it was 1,120,240. Most of this increase is the result of spotted alfalfa aphid control. In addition, a large acreage was treated by ground rigs.

In addition to the direct effects on alfalfa production through increased costs and lowered yields, the spotted alfalfa aphid affected hay quality and stands, and often made harvesting difficult (Davis, *et al.*, 1957).

[7] Estimates compiled by State Bureau of Chemistry from reports of agricultural pest control operators.

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In this long and involved project many people have assisted in many ways. I am especially indebted to the members of the University of California Agricultural Extension Service and the county agricultural commissioners who so carefully followed the spread of *Therioaphis* in their counties. The list of collectors in the appendix is an indication of those who have contributed. F. L. Blanc and others in the Bureau of Entomology of the State Department of Agriculture have been most coöperative and have contributed much valuable information on the aphid's spread. Jack E. Dibble spent much of the 1956 season on this project and assisted greatly in tracing the spread that year. Others who have contributed in special ways and to whom I wish to express my thanks are Lloyd Andres, B. B. Burlingame, Vernon E. Burton, C. S. Davis, A. S. Deal, Robert C. Dickson, Richard Eide, Harry Graham, O. D. McCutcheon, John Nickel, H. T. Reynolds, W. R. Sallee, F. E. Souther, E. E. Stevenson, John E. Swift, Orion Tatro, and G. P. Willsey. In addition I wish to thank my colleagues, Paul D. Hurd, Jr., K. S. Hagen, J. E. Swift, and E. G. Linsley, who critically reviewed this manuscript in its early stages. George P. Willsey prepared the maps and graphs and Celeste Green, the aphid drawings.

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APPENDIX

In the following appendix are listed the significant records that have been reported on the spread of *Therioaphis maculata* in California. An attempt has been made to record the exact locality, time, and collector of the aphid in each county when it occurred for the first time. In addition, so far as possible, the spread of the aphid within the counties is detailed. The times when responsible local agricultural authorities considered their counties to be completely infested are given when available. The affiliation of the collectors is abbreviated as follows: AES—University of California, Agricultural Extension Service; Ag. C.—local county Department of Agriculture; CDA—California State Department of Agriculture; UCB—University of California, Department of Entomology and Parasitology, Berkeley; UCD—University of California, Department of Entomology and Parasitology, Davis; UCR—University of California, Department of Entomology, Riverside; and USDA—United States Department of Agriculture, Agricultural Research Service. Where a determiner is not listed it may be assumed that the determination was made by the collector. It is on these records and other personal observations that the maps presented in figures 5 to 20 are based.

Locality	County	Date	Collector	Affiliation	Determiner	Remarks
Bard	Imperial	June 17, 1954	Andrew S. Deal	AES	.....	Winged forms on cotton. Earliest Imperial Co. record. Observed but not collected
Orita	Imperial	June 23, 1954	Robert Kortsen	AES	R. C. Dickson	First recognized infestation in Calif. First reported economic damage
Holtville	Imperial	June 28, 1954	R. C. Dickson	UCR	.....	
Blythe	Riverside	Mid-June, 1954	Charles Edwards	Blythe Alfalfa Growers	Charles Edwards	First Riverside Co. record. Observed but not collected
Brawley	Imperial	June 30, 1954	G. H. Schwegel	Ag. C.	F. L. Blanc	
			W. N. Kimbrell	Ag. C.		
			Cy Gammon	CDA		
Niland	Imperial	July 1, 1954	R. C. Dickson	UCR		
Westmorland	Imperial	July 2, 1954	R. C. Dickson	UCR		
Orita District	Imperial	July 7–8, 1954	Andrew S. Deal	AES		Area 6–8 miles in diameter infested economically
			H. T. Reynolds	UCR		
			R. C. Dickson	UCR		
			J. E. Swift	AES		
Bond's corner (E. of Calexico)	Imperial	July 8, 1954	R. C. Dickson	UCR		
El Centro	Imperial	July 15, 1954	R. C. Dickson	UCR		Imperial Co. completely infested
Nuevo	Riverside	Sept. 22, 1954	Jim Dewlan	Ag. C.		
			Kem Foulke	Ag. C.	F. L. Blanc	
Hemet area	Riverside	Sept. 28, 1954	Robert Howie	Ag. C.		Probably in this area in August
			L. D. Anderson	UCR		
			H. T. Reynolds	UCR		
Coachella Valley	Riverside	Oct. 1, 1954	Elmer C. Kennedy	Ag. C.		
			Earl Asher	Ag. C.		
			Howard M. Cook	Ag. C.		
Borrego	San Diego	Oct. 18, 1954	J. P. Dion	Ag. C.	R. F. Wilkey	Economic infestations
Newberry	San Bernardino	Nov. 7, 1954	Robert C. Harkens	AES	E. O. Essig	First San Bernardino Co. record
Home Gardens	Riverside	Dec. 2, 1954	Wayne L. Howe	USDA		Rumored to have been in Riverside in October
Irvine	Orange	Dec. 8, 1954	Wayne L. Howe	USDA	W. L. Howe	First Orange Co. record
Menifee Valley	Riverside	Dec. 9, 1954	Elmer C. Kennedy	Ag. C.		
Elsinore	Riverside	Dec. 9, 1954	Elmer C. Kennedy	Ag. C.		
Needles	San Bernardino	Dec. 10, 1954	Robert C. Harkens	AES		
LaHabra	Orange	Dec. 13, 1954	Richard A. Smith	Ag. C.	R. A. Smith	
Brea	Orange	Dec. 13, 1954	Richard A. Smith	Ag. C.	R. A. Smith	
6 miles S.E. Lancaster, 40th St. E. and Ave. M	Los Angeles	Dec. 14, 1954	L. D. McCorkindale	Ag. C.	L. E. Meyrs	First Los Angeles Co. record
Buena Park	Orange	Dec. 15, 1954	Richard A. Smith	Ag. C.	R. A. Smith	
La Mirada	Los Angeles	Dec. 22, 1954	Wayne L. Howe	USDA		

and Fairfax Rd.	Kern	Jan. 25, 1955	Guy Beevor	CDA	F. L. Blanc	First record for Kern Co. and first north of Tehachapi Mountains
Puente	Los Angeles	Feb. 1, 1955	Guy Beevor	CDA		
			Robert McCaslin	Ag. C.		
Santa Susana	Ventura	Feb. 8, 1955	Guy Beevor	CDA	F. L. Blanc	First record for Ventura Co.
			H. E. Bronson	Ag. C.		
San Bernardino	San Bernardino	Feb. 10, 1955	Robert C. Harkens	AES		
Lakeside	San Diego	Feb. 24, 1955	J. P. Dion	Ag. C.	F. L. Blanc	
			Guy Beevor	CDA		
Ramona	San Diego	Feb. 24, 1955	Guy Beevor	CDA	G. T. Okumura	
			J. P. Dion	Ag. C.		
Barona	San Diego	Feb. 24, 1955	Guy Beevor	CDA	G. T. Okumura	
			J. P. Dion	Ag. C.		
Colton	San Bernardino	Feb. 28, 1955	Wendell Young	Ag. C.		
			Gene Harper	Ag. C.		
Grand Terrace	San Bernardino	Feb. 28, 1955	Wendell Young	Ag. C.		
			Gene Harper	Ag. C.		
Yucaipa	San Bernardino	Feb. 28, 1955	Wendell Young	Ag. C.		
Highland	San Bernardino	Feb. 28, 1955	Wendell Young	Ag. C.		
Jamul	San Diego	March 3, 1955	J. P. Dion	Ag. C.	R. F. Wilkey	
Little Rock	Los Angeles	March 3, 1955	L. D. McCorkindale	Ag. C.	F. L. Blanc	
Ontario	San Bernardino	March 7, 1955	Merle J. Worthy	Ag. C.		San Bernardino Co. probably completely infested
			Ken Palmer	Ag. C.		
Beaumont	Riverside	March 15, 1955	Guy Beevor	CDA		
			Crawford Cordill	Ag. C.		
Castaic	Los Angeles	March 21, 1955	Elmer C. Kennedy	Ag. C.		Rumored to have been in this area in Oct. 1954
			Robert van den Bosch	UCR		
Fontana	San Bernardino	March 29, 1955	H. T. Reynolds	UCR		
Fillmore	Ventura	April 11, 1955	Robert C. Harkens	AES		
			Omar Myers	Ag. C.		
3 miles S.E. Clovis	Fresno	April 13, 1955	Harry Michel	Ag. C.		
			H. V. Dunnegan	Ag. C.	F. L. Blanc	First record for Fresno Co. and northernmost record of this date
Magunden area	Kern	April 15, 1955	V. E. Burton	AES		General infestation in this area
Oxnard	Ventura	April 18, 1955	Clyde May	Ag. C.		
Camarillo	Ventura	April 19, 1955	W. M. Jones	Ag. C.		
Ventura	Ventura	April 20, 1955	Verner Holmer	Ag. C.		
			Al Bicker	Ag. C.		
7 miles W. Lancaster, 75th St. West and Ave. I	Los Angeles	April 25, 1955	L. D. McCorkindale	Ag. C.		
10 miles N.W. Lancaster, 75th St. W. and Ave. B	Los Angeles	April 27, 1955	L. D. McCorkindale	Ag. C.		
Bakersfield	Kern	April 29, 1955	Roy Parker	AES	V. E. Burton	

Locality	County	Date	Collector	Affiliation	Determiner	Remarks
Saugus	Los Angeles	April 29, 1955	Chas. W. Yerxa	Ag. C.		
2 miles S.E. Selma	Fresno	May 3, 1955	John Gore	Ag. C.	F. L. Blanc	
Corona	Riverside	May, 1955	Elmer Kennedy	Ag. C.		
Saco, 2 miles N. Bakersfield	Kern	May 12, 1955	V. E. Burton	AES		
Comanche Pt., 8 miles S. Arvin	Kern	May 12, 1955	V. E. Burton	AES		
Weedpatch	Kern	May 12, 1955	V. E. Burton	AES		
Arvin	Kern	May 12, 1955	V. E. Burton	AES		
Canoga Park	Los Angeles	May 19, 1955	Chas. W. Yerxa	Ag. C.		
			Ed. D. Williams	Ag. C.		
2½ miles N. E. Clovis, Shepard and Temperance Rd.	Fresno	May 23, 1955	John Gore	Ag. C.	F. L. Blanc	
Moose Canyon, Escondido	San Diego	May 31, 1955	Lloyd A. Newell	Ag. C.	G. T. Okumura	
Harper Lake	San Bernardino	June 1, 1955	Ray Schneider	Ag. C.		
			Lee Dolch	Ag. C.		
3 miles S. Berenda	Madera	June 7, 1955	Ray F. Smith	UCB	E. O. Essig	First Madera Co. record and northernmost record of this date
3 miles S. Old River	Kern	June 8, 1955	V. E. Burton	AES		
2 miles S.W. McFarland	Kern	June 8, 1955	V. E. Burton	AES		
3 miles E. McFarland	Kern	June 8, 1955	V. E. Burton	AES		
Willow Springs, Rosamond area	Kern	June 8, 1955	Roy Parker	AES	V. E. Burton	
9 miles E. Hanford	Kings	June 9, 1955	R. F. Smith	UCB	E. O. Essig	First Kings Co. record
14 miles S. Poplar	Tulare	June 9, 1955	R. F. Smith	UCB	E. O. Essig	First Tulare Co. record
35 miles W. Lancaster	Los Angeles	June 15, 1955	Norman Hazel			
1 mile N. Rosedale	Kern	June 15, 1955	R. F. Smith	UCB	E. O. Essig	
			Lloyd Andres	UCB		
Westminster	Orange	June 25, 1955	R. J. Bumgardner	Ag. C.	R. Bumgardner	
			F. G. Larmer	Ag. C.		
Lamont	Kern	June 27, 1955	Kirk Harper	Ag. C.		
1 mile S. Visalia	Tulare	June 30, 1955	Wm. Sallee	AES	E. O. Essig	First economic damage in Kern Co.
——	Orange	July 1, 1955	R. J. Bumgardner	Ag. C.		Orange Co. completely infested
2 miles W. Dinuba	Tulare	July 1, 1955	Wm. Sallee	AES	E. O. Essig	
3 miles S. Tulare	Tulare	July 8, 1955	Wm. Sallee	AES	E. O. Essig	
1 mile E. Hanford	Kings	July 17, 1955	O. D. McCutcheon	AES	E. O. Essig	Severe infestation
5 miles S.E. Visalia	Tulare	July 18, 1955	William Sallee	AES		First economic infestation in Tulare Co.
Guernsey	Kings	July 20, 1955	O. D. McCutcheon	AES		Light infestation
Yettem	Tulare	July 21, 1955	Wm. Sallee	AES		
Dinuba	Tulare	July 22, 1955	Wm. Sallee	AES		Light infestation

		July 26, 1955	Clarence Johnson	AES		
Excelsior	Kings	July 27, 1955	O. D. McCutcheon	AES		Light infestation
Armona	Kings	July 28, 1955	O. D. McCutcheon	AES		Light infestation
7 miles N.W. Tulare	Tulare	July 29, 1955	Wm. Sallee	AES		
Waukena	Tulare	July 29, 1955	Wm. Sallee	AES		
Goshen	Tulare	July 29, 1955	Wm. Sallee	AES		
Weldon	Kern	July 30, 1955	V. L. Burton	AES		Heavy infestation
			Roy Parker	AES		
2 miles N. Merced	Merced	July 31, 1955	Chester C. Conley	AES	E. O. Essig	First Merced Co. record
Gregg	Madera	Aug. 1, 1955	Clarence Johnson	AES		
Hub	Kings	Aug. 1, 1955	O. D. McCutcheon	AES		Light infestation
Hardwick	Kings	Aug. 1, 1955	O. D. McCutcheon	AES		Light infestation
San Luis Rey Mission	San Diego	Aug. 3, 1955	Les Haworth	Ag. C.	F. L. Blanc	
			Mel Hess	Ag. C.		
Easton	Fresno	Aug. 4, 1955	Richard Eide	AES		
2 miles S.W. of Navalencia	Fresno	Aug. 4, 1955	Richard Eide	AES		
Rolinda	Fresno	Aug. 4, 1955	Richard Eide	AES		
Tipton, Earlimart area	Tulare	Aug. 8, 1955	Wm. Sallee	AES		
Ivanhoe	Tulare	Aug. 8, 1955	Wm. Sallee	AES		
Woodlake	Tulare	Aug. 8, 1955	Wm. Sallee	AES		
Exeter	Tulare	Aug. 8, 1955	Wm. Sallee	AES		
Corcoran	Kings	Aug. 8, 1955	O. D. McCutcheon	AES		Light infestation
5 miles E. Stratford	Kings	Aug. 8, 1955	O. D. McCutcheon	AES		Light infestation
4 miles S.E. Merced	Merced	Aug. 8, 1955	W. W. Allen	UCB	E. O. Essig	
			Geo. Schaeffers	UCB		
5 miles N.W. Chowchilla	Merced	Aug. 8, 1955	W. W. Allen	UCB	E. O. Essig	
			Geo. Schaeffers	UCB		
Chowchilla	Madera	Aug. 8, 1955	W. W. Allen	UCB	E. O. Essig	
			Geo. Schaeffers	UCB		
Califa	Madera	Aug. 8, 1955	W. W. Allen	UCB	E. O. Essig	
			Geo. Schaeffers	UCB		
1 mile N. Atwater	Merced	Aug. 9, 1955	W. W. Allen	UCB	E. O. Essig	
			Geo. Schaeffers	UCB		
Livingston	Merced	Aug. 9, 1955	W. W. Allen	UCB	E. O. Essig	
			Geo. Schaeffers			
6 miles W. Merced	Merced	Aug. 9, 1955	W. W. Allen	UCB	E. O. Essig	
			Geo. Schaeffers	UCB		
2 miles S. San Miguel on River Road	San Luis Obispo	Aug. 19, 1955	R. M. Drake	Ag. C.	F. L. Blanc	First San Luis Obispo Co. record
Estrella	San Luis Obispo	Aug. 22, 1955	Robert Marshall	Agriform Co.	Sherwin Thomas	
Templeton	San Luis Obispo	Aug. 23, 1955	Roger Drake	Ag. C.	F. L. Blanc	
Shandon	San Luis Obispo	Aug. 24, 1955	Roger Drake	Ag. C.	F. L. Blanc	
Atascadero	San Luis Obispo	Aug. 24, 1955	Roger Drake	Ag. C.	F. L. Blanc	

Locality	County	Date	Collector	Affiliation	Determiner	Remarks
Tehachapi	Kern	Aug. 25, 1955	Sherman Grant			
Buttonwillow	Kern	Aug. 25, 1955	Lloyd Andres	UCB	E. O. Essig	
4 miles S.E. Modesto	Stanislaus	Aug. 25, 1955	Eugene Stevenson	AES	E. O. Essig	First Stanislaus Co. record
			Al Volz	AES	F. L. Blanc	
			L. E. Macomber	Ag. C.		
Lemoore	Kings	Aug. 26, 1955	O. D. McCutcheon	AES		Heavy infestation
3 miles S. Ceres	Stanislaus	Aug. 26, 1955	E. Stevenson	AES		
2 miles S. Hughson	Stanislaus	Aug. 26, 1955	E. Stevenson	AES		
2 miles S. E. Turlock	Stanislaus	Aug. 26, 1955	E. Stevenson	AES		
2 miles N.W. Turlock	Stanislaus	Aug. 26, 1955	E. Stevenson	AES		
Raisin City	Fresno	Sept. 1, 1955	Richard Eide	AES		
Carruthers	Fresno	Sept. 1, 1955	Richard Eide	AES		
Herndon	Fresno	Sept. 1, 1955	Richard Eide	AES		
Biola	Fresno	Sept. 1, 1955	Richard Eide	AES		
1 mile S. Gerber	Tehama	Sept. 2, 1955	Lin Maxwell	AES	E. O. Essig	First Tehama Co. record and northernmost record in state as of this date
1 mile S. Carbona	San Joaquin	Sept. 6, 1955	Dwight Worsham		F. L. Blanc	First San Joaquin Co. record
1 mile W. Corning	Tehama	Sept. 6, 1955	Lin Maxwell	AES		
3 miles N. Los Molinos	Tehama	Sept. 7, 1955	E. O. Burrill	Ag. C.	E. O. Essig	
Ridgecrest	Kern	early Sept., 1955	V. E. Burton	AES		
Cantil	Kern	early Sept., 1955	V. E. Burton	AES		
Red Bluff	Tehama	Sept. 7, 1955	Steve Ancell	Ag. C.		
1 mile N.W. Dairyville	Tehama	Sept. 7, 1955	E. O. Burrill	Ag. C.	E. O. Essig	
4 miles E. Red Bluff, Antelope Valley	Tehama	Sept. 7, 1955	E. O. Burrill	Ag. C.	E. O. Essig	Northernmost record in state as of this date
5 miles E. Corning	Tehama	Sept. 8, 1955	Lin Maxwell	AES		
Capay	Tehama	Sept. 8, 1955	E. L. Dietz	Ag. C.	F. L. Blanc	
Capay	Glenn	Sept. 8, 1955	E. O. Burrill	Ag. C.		First Glenn Co. record
Richfield	Tehama	Sept. 8, 1955	E. L. Dietz	Ag. C.	F. L. Blanc	
1.5 mi. S.E. Manteca	San Joaquin	Sept. 10, 1955	R. S. Baskett	AES		
6 miles E. Waterford	Stanislaus	Sept. 13, 1955	E. Stevenson	AES		
Hilmar	Merced	Sept. 14, 1955	Earl Burton	Ag. C.		
Los Banos	Merced	Sept. 14, 1955	Chester Conley	AES	E. O. Essig	
Kettleman City	Kings	Sept. 15, 1955	L. C. Brown	AES		Light
1 mi. W. Salida	Stanislaus	Sept. 15, 1955	L. E. Macomber	Ag. C.	L. E. Macomber	
Parkfield	Monterey	Sept. 16, 1955	Dan Irving	AES	E. O. Essig	First Monterey Co. record
Indian Valley	Monterey	Sept. 16, 1955	Dan Irving	AES	E. O. Essig	
Santa Margarita	San Luis Obispo	Sept. 19, 1955	Roger Drake	Ag. C.	F. L. Blanc	
5 miles W. Manteca	San Joaquin	Sept. 20, 1955	R. S. Baskett	AES		
6 miles N. Red Bluff	Tehama	Sept. 22, 1955	Wally Schreader	AES		Northernmost record in state as of this date

7 miles S.W. San Jose	Santa Clara	Sept. 29, 1955	Loren W. Hellwig	Ag. C.	F. L. Blanc	
Roseville	Placer	Sept. 30, 1955	R. F. Smith	UCB	E. O. Essig	Heavy infestation
Gustine	Merced	Oct. 1, 1955	Glenn Berry	Ag. C.	F. L. Blanc	First Placer Co. record
Dos Palos	Merced	Oct. 1, 1955	E. A. Danison	Ag. C.		
2 miles E. Hamilton City	Butte	Oct. 3, 1955	Bob Milbourn	Ag. C.		
12 miles N.W. Chico, Cana Road	Butte	Oct. 5, 1955	Donald Black	Ag. C.	F. L. Blanc	First Butte Co. record
Antelope	Sacramento	Oct. 5, 1955	W. J. Nicholas		H. L. McKenzie	
			R. F. Wilkey	CDA		First Sacramento Co. record
Elverta	Sacramento	Oct. 5, 1955	F. L. Blanc	CDA		
			R. F. Wilkey	CDA		
North Sacramento	Sacramento	Oct. 5, 1955	F. L. Blanc	CDA		
			R. F. Wilkey	CDA		
Carrizo Plains	San Luis Obispo	Oct. 5, 1955	F. L. Blanc	CDA		
Nipomo	San Luis Obispo	Oct. 5, 1955	Roger Drake	Ag. C.	F. L. Blanc	
Citrus Heights	Sacramento	Oct. 6, 1955	Roger Drake	Ag. C.	F. L. Blanc	
			J. C. Wilson	Ag. C.		
Orangevale	Sacramento	Oct. 6, 1955	O. L. Houts	Ag. C.	F. L. Blanc	
			J. C. Wilson	Ag. C.		
Fair Oaks	Sacramento	Oct. 6, 1955	O. L. Houts	Ag. C.	F. L. Blanc	
			J. C. Wilson	Ag. C.		
Hamilton City	Glenn	Oct. 7, 1955	O. L. Houts	Ag. C.	F. L. Blanc	
4 miles W. Chico	Butte	Oct. 8, 1955	A. H. Retan	AES	E. O. Essig	
San Ardo	Monterey	Oct. 9, 1955	Morton D. Morse	AES		
2 miles S.E. Gridley	Butte	Oct. 10, 1955	R. V. Emparan	Ag. C.		
2 miles S.W. Hamilton City	Glenn	Oct. 10, 1955	A. H. Retan	AES		
			Harry McCracken	Ag. C.	F. L. Blanc	
3 miles E. Biggs	Butte	Oct. 11, 1955	Willis Farnsworth	Ag. C.		
Courtland	Sacramento	Oct. 11, 1955	D. L. Graves	Ag. C.	G. T. Okumura	
			O. L. Houts	Ag. C.	F. L. Blanc	
Ryer Island	Solano	Oct. 13, 1955	P. F. Stambough	Ag. C.		
Cottonwood	Shasta	Oct. 14, 1955	John Golden	Ag. C.	F. L. Blanc	First Solano Co. record
Sheridan	Placer	Oct. 14, 1955	Glenn Shannon	Ag. C.	F. L. Blanc	First Shasta Co. record
1 mile S.E. Anderson	Shasta	Oct. 14, 1955	Glenn Berry	Ag. C.	F. L. Blanc	
6 miles S.E. Redding	Shasta	Oct. 15, 1955	Bruce Wade	Ag. C.		Northernmost record in state as of this date
5½ miles N. Manteca	San Joaquin	Oct. 15, 1955	Glenn Shannon	Ag. C.		
Bryte	Yolo	Oct. 17, 1955	R. S. Baskett	AES		
Liberty Island	Solano	Oct. 17, 1955	John Bartels	Ag. C.	F. L. Blanc	First Yolo Co. record
Holland Island	Solano	Oct. 17, 1955	John Golden	Ag. C.	F. L. Blanc	
Dixon	Solano	Oct. 17, 1955	John Golden	Ag. C.	F. L. Blanc	
Eggbert	Solano	Oct. 18, 1955	John Golden	Ag. C.		
E. Stockton	San Joaquin	Oct. 19, 1955	John Golden	Ag. C.	F. L. Blanc	
			R. S. Baskett	AES		

Locality	County	Date	Collector	Affiliation	Determiner	Remarks
2 miles N. Waterloo	San Joaquin	Oct. 20, 1955	R. S. Baskett	AES		
Sisquoc	Santa Barbara	Oct. 20, 1955	R. W. Allen	Ag. C.	R. F. Wilkey	First Santa Barbara Co. record
			B. Silva	Ag. C.		
4 miles N.E. Redding	Shasta	Oct. 25, 1955	Glenn Shannon	Ag. C.		
Millville	Shasta	Oct. 26, 1955	Glenn Shannon	Ag. C.		Roadside plants
3 miles N.E. Bella Vista	Shasta	Oct. 30, 1955	Bruce Wade	Ag. C.		
Montgomery Creek	Shasta	Oct. 30, 1955	Bruce Wade	Ag. C.		Northernmost record in California in 1955
3 miles S.W. Sacramento	Yolo	Oct. 31, 1955	John Bartels	Ag. C.	F. L. Blanc	
Watsonville	Santa Cruz	Nov. 1, 1955	D. H. Shaw	Ag. C.	F. L. Blanc	First Santa Cruz Co. record
4 miles W. Escalon	San Joaquin	Nov. 1, 1955	R. S. Baskett	AES		
10 miles N.W. Avalon, Catalina Island	Los Angeles	Nov. 3, 1955	Allen D. Propst		J. E. Swift	
Roberts Island	San Joaquin	Nov. 5, 1955	Wm. Fischer			
9 miles W. Firebaugh	Fresno	Nov. 9, 1955	L. M. Cox	Ag. C.	R. F. Wilkey	
San Martin	Santa Clara	Nov. 9, 1955	M. S. Beckley	AES	J. E. Swift	
Gilroy	Santa Clara	Nov. 9, 1955	M. S. Beckley	AES	J. E. Swift	
Panoche	San Benito	Nov. 9, 1955	H. W. Collins	AES		First San Benito Co. record
1 mile N. E. Gary	Santa Barbara	Nov. 10, 1955	R. W. Allen	Ag. C.	H. L. McKenzie	
			B. Silva	Ag. C.		
1 mile S.E. Oakley	Contra Costa	Nov. 10, 1955	Harry Graham	UCB	E. O. Essig	First Contra Costa Co. record
			Lloyd Andres	UCB		
2 miles N.W. Vernalis	San Joaquin	Nov. 11, 1955	R. S. Baskett	AES		
Galt	Sacramento	Nov. 11, 1955	S. P. Carlson	AES		
2 miles W. Oakdale	Stanislaus	Nov. 15, 1955	L. E. Macomber	Ag. C.	L. E. Macomber	
			F. E. Hayes	Ag. C.		
1 mile E. Irvington	Alameda	Nov. 23, 1955	Everett Henning	Ag. C.	F. L. Blanc	First Alameda Co. record
3 miles N.W. Yuba City	Sutter	Nov. 28, 1955	J. H. Lindt	AES	E. O. Essig	First Sutter Co. record
Cuyama	Santa Barbara	Nov. 29, 1955	J. S. Rowell	Ag. C.		
Buellton	Santa Barbara	Dec. 7, 1955	Raymond Watson	Ag. C.	F. L. Blanc	
3 miles E. Patterson	Stanislaus	Dec. 7, 1955	E. E. Stevenson	AES		
4 miles N.E. Crows Landing	Stanislaus	Dec. 7, 1955	E. E. Stevenson	AES		
Santa Ynez	Santa Barbara	Dec. 8, 1955	Roger Allen	Ag. C.		
Lompoc	Santa Barbara	Dec. 8, 1955	R. Allen	Ag. C.		
			George Davis	Ag. C.		
3 miles N. Mtn. House	Alameda	Dec. 8, 1955	Everett Henning	Ag. C.	F. L. Blanc	
2 miles S.E. Five Points	Fresno	Dec. 8, 1955	Armen Sarquis	AES		Fresno Co. completely infested
			Richard Eide	AES		
1 mile S. Huron	Fresno	Dec. 8, 1955	Armen Sarquis	AES		
			Richard Eide	AES		

			Richard Eide	AES		
13 miles E. Coalinga	Fresno	Dec. 8, 1955	Armen Sarquis	AES		
			Richard Eide	AES		
Los Olivos	Santa Barbara	Dec. 9, 1955	Ray Watson	Ag. C.		
Solvang	Santa Barbara	Dec. 9, 1955	Ray Watson	Ag. C.		
Arroyo Grande	San Luis Obispo	Jan. 3, 1956	R. M. Drake	Ag. C.		
Goleta	Santa Barbara	Jan. 10, 1956	R. J. Reid	Ag. C.	H. L. McKenzie	
Cuyama Valley	Ventura	Jan. 17, 1956	John Allee	Ag. C.		
			Robert Burleson	Ag. C.		
			Richard Jenkins	Ag. C.		
Olancha	Inyo	March 1, 1956	D. Barry Leeson	AES	E. O. Essig	H. T. Reynolds *(in litt.)* states this area was probably infested in late August or early Sept. 1955 and Lone Pine later in the fall
Coopers	Monterey	March 14, 1956	J. Drea	UCB		
			D. Paschke	UCB		
2 miles S. Chualar	Monterey	March 14, 1956	J. Drea	UCB		
			D. Paschke	UCB		
Greenfield	Monterey	March 14, 1956	J. Drea	UCB		
			D. Paschke	UCB		
Ojai	Ventura	March 15, 1956	Earl Kalar	Ag. C.		
			Fred Lewis	Ag. C.		
Independence	Inyo	April 3, 1956	H. T. Reynolds	UCR		
1 mile E. Wheatland	Yuba	May 23, 1956	Loren Hellwig	Ag. C.		
4 miles N. Marysville	Yuba	May 23, 1956	Loren Hellwig	Ag. C.		
Knightsen	Contra Costa	May 29, 1956	K. Danielson	Ag. C.	F. L. Blanc	
			W. Meese	Ag. C.		
Bethel Island	Contra Costa	May 31, 1956	K. E. Danielson	Ag. C.	R. F. Wilkey	
Orland	Glenn	June 19, 1956	C. Cordill	Ag. C.	C. Cordill	
6 miles S. Big Pine	Inyo	June 22, 1956	D. Barry Leeson	AES		
Glenn	Glenn	June 28, 1956	C. Cordill	Ag. C.	C. Cordill	
Woodland	Yolo	July 2, 1956	J. Dibble	AES		
Davis	Yolo	July 3, 1956	E. H. Stanford	UCD		
1 mi. E. San Juan Bautista	San Benito	July 5, 1956	H. Bill Collins	AES		Yolo Co. generally infested
2 miles S. San Felipe	San Benito	July 5, 1956	H. Bill Collins	AES		San Benito Co. completely infested
4 miles S.E. Paicines	San Benito	July 5, 1956	H. Bill Collins	AES		
5 miles S. Orland	Glenn	July 6, 1956	J. Dibble	AES		
Pacheco	Contra Costa	July 16, 1956	K. E. Danielson	Ag. C.		First record in western Contra Costa Co.
			L. Masini	Ag. C.		
Maxwell	Colusa	July 24, 1956	W. O. Marshall	AES		
1 mile W. Bishop	Inyo	July 26, 1956	D. Barry Leeson	AES		First Colusa Co. record
Priest Valley	Monterey	July 26, 1956	Dan Irving	AES		
Grapevine	Glenn	Aug. 1, 1956	R. B. Jeter	AES		
3 miles W. Willows	Glenn	Aug. 1, 1956	R. B. Jeter	AES		
2 miles N. Glenn	Glenn	Aug. 1, 1956	R. B. Jeter	AES		Glenn Co. completely infested

Locality	County	Date	Collector	Affiliation	Determiner	Remarks
Lockwood	Monterey	Aug. 8, 1956	Harry Agmalian	AES		
10 miles W. Greenfield	Monterey	Aug. 8, 1956	Dan Irving	AES		
Williams	Colusa	Aug. 28, 1956	K. H. Ingebretsen	AES		
Cambria	San Luis Obispo	Aug. 30, 1956	Don Wood	Ag. C.	Roger Drake	
Nicolaus	Sutter	Aug. 30, 1956	J. H. Lindt	AES		
Verona	Sutter	Aug. 30, 1956	J. H. Lindt	AES		
3 miles S.W. Sutter	Sutter	Aug. 30, 1956	J. H. Lindt	AES		
2 miles N.W. Tudor	Sutter	Aug. 30, 1956	J. H. Lindt	AES		Sutter Co. completely infested
Meridian	Sutter	Sept. 15, 1956	J. H. Lindt	AES		
Ione	Amador	Sept. 21, 1956	R. E. Plaister	AES		First Amador Co. record
Benton	Mono	September, 1956	D. Barry Leeson	AES		First Mono Co. record
——	Colusa	Late Sept., 1956	F. F. Swim	Ag. C.		Colusa Co. completely infested
4 miles N.E. Defender	Amador	Oct. 3, 1956	R. E. Plaister	AES		
Livermore	Alameda	Oct. 6, 1956	Neil Overgaard	Ag. C.		
Rutherford	Napa	Oct. 24, 1956	Henry Stabo	Ag. C.		First Napa Co. record
Yountville	Napa	Oct. 25, 1956	Henry Stabo	Ag. C.		
6 miles N. San Andreas	Calaveras	Dec. 12, 1956	R. P. Allen	CDA		First Calaveras Co. record
			W. B. Andahl	Ag. C.		
Middletown	Lake	Mar. 26, 1957	W. Cruickshank	Ag. C.	F. L. Blanc	First Lake Co. record
			W. Wiard	CDA		
Lower Lake	Lake	Mar. 26, 1957	W. Cruickshank	CDA	F. L. Blanc	
			W. Wiard	CDA		
5 miles E. Hopland	Mendocino	Mar. 27, 1957	A. DeGrasse	Ag. C.	H. L. McKenzie	First Mendocino Co. record
			W. Wiard	CDA		
Susanville	Lassen	June 21, 1957	L. E. Wheeler	Ag. C.		First Lassen Co. record
			H. T. Osborn	CDA		
Cloverdale	Sonoma	July 8, 1957	R. L. Sisson	AES	R. L. Sisson	First Sonoma Co. record
Alexander Valley	Sonoma	July 8, 1957	R. L. Sisson	AES		
Dry Creek	Sonoma	July 8, 1957	R. L. Sisson	AES		
Healdsburg	Sonoma	July 8, 1957	R. L. Sisson	AES		
Windsor	Sonoma	July 8, 1957	R. L. Sisson	AES		
10 miles W. Santa Rosa	Sonoma	July 8, 1957	R. L. Sisson	AES		
Sonoma	Sonoma	July 9, 1957	R. L. Sisson	AES		
Cotati	Sonoma	July 9, 1957	R. L. Sisson	AES		
Hat Creek	Shasta	Aug. 10, 1957	Francis F. Smith	AES		
Fall River Valley	Shasta	Aug. 10, 1957	Francis F. Smith	AES		Shasta Co. completely infested
2½ miles N. Montague	Siskiyou	Sept. 24, 1957	Cliff Giebner	Ag. C.		First Siskiyou Co. record. Northernmost record in California in 1957
Gazelle	Siskiyou	Oct. 7, 1957	Cliff Giebner	Ag. C.		
Scott Valley	Siskiyou	Oct. 15, 1957	Cliff Giebner	Ag. C.		
4 miles N.W. Placerville	Eldorado	Dec. 19, 1957	E. F. Veerkamp	Ag. C.		First Eldorado Co. record
			W. W. Wiard	CDA		